

GUIDELINES FOR HIGHWAY DELINEATION

FINAL REPORT

BY

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BUREAU OF RESEARCH AND DEMONSTRATION**

IN COOPERATION WITH

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16. Abstract This project advanced the implementation of current technical knowledge in many areas of delineation and clarified the position of the New Jersey Department of Transportation's units and management on unresolved issues. By reviewing literature, making field inspections, and from interviews of professionals, delineation needs and issues were developed. Decisions on delineation issues were made from questionnaire surveys and meetings of New Jersey Department of Transportation managers and professionals. The recommended "Guidelines for Highway Delineation." were based on questionnaire and meeting results. Implementation of the Guidelines is recommended to achieve cost-effective, safe, and consistent use of highway delineation.			
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SUMMARY AND CONCLUSIONS

This project advanced the implementation of current technical knowledge in many areas of delineation and clarified the position of the New Jersey Department of Transportation's units and management on unresolved issues. Using published research results, existing manuals, interviews of delineation professionals and field observations of delineation systems, standing technical issues relevant to the state of the art in New Jersey were identified and developed. Through the use of questionnaires and meetings, consensus resolutions to many of these delineation issues were found. The Guidelines for Highway Delineation were written from the results of the questionnaires and meetings. Not all issues could be resolved, however. For example, New Jersey Department of Transportation professionals identified maintenance of roadway delineation as an issue. However, no technical problems were identified because this is a matter of available resources and managerial priority.

RECOMMENDATIONS

The New Jersey Department of Transportation should fully implement the roadway delineation methods and techniques detailed in the "Guidelines for Highway Delineation." These guidelines are the major technical product of this research effort.

IMPLEMENTATION OF FINDINGS

The Bureau of Research and Demonstration will propose the guidelines for implementation by relevant units in the New Jersey Department of Transportation. Many of these units participated in the process of developing guidelines and have already indicated their support as a result of their involvement.

Some more conveniently packaged memos will serve to provide delineation information to New Jersey Department of Transportation personnel.

The meetings that were held and reports and questionnaires that were distributed throughout the project also were valuable for communicating delineation ideas and findings.

INTRODUCTION

Roadway delineation is used to control the placement and movements of traffic by supplying visual information that identifies the safe and legal limits of the travelled way, regulates the direction of travel, lane changing, and passing, marks lanes or zones where maneuvers such as turns or parking are permitted, required, or restricted, and aids in identifying potentially hazardous situations such as obstacles or crosswalks.(1) Reduced visibility at night forces drivers to rely almost exclusively on formal delineation for vehicle guidance and control.(2) Nighttime driving is becoming more hazardous than daytime driving and the nighttime percentage of fatalities is increasing.(3) Inadequate night visibility is considered to be the primary contributor to serious accidents with or without alcohol.(4) Visibility may be improved by more consistent and widespread use of reflectorized delineation.(5) Implementation of delineation guidelines would provide uniformity for New Jersey Department of Transportation (NJDOT) practice in design, maintenance, highway safety programs, and construction.

Previously, guidelines on the use of delineation have been developed for only some treatments used on New Jersey state highways. The research project "Guidelines for Highway Delineation" is different from most other research projects. The project synthesizes available delineation research results, along with the expert opinions of New Jersey Department of

Transportation professionals into guidelines covering various types of roadway delineation. The objectives of the study are:

1. to select the delineation devices and methods that are ready to use and determine a consensus for the use of such devices in different geometric and environmental situations, and
2. to determine which delineation systems are not ready to use but have promising future potential and prepare research problem statements where interest in further investigation is determined.

PROCEDURE

Four basic data sources were used throughout the research project: 1) research literature, 2) field observations, 3) policies and manuals, and 4) structured interviews and questionnaire surveys of professionals. The work progressed along a course that led from very general delineation needs and priorities to the identification of specific technical issues and finally to finding consensus for resolution of the issues. This procedure is shown in Figure 1. Emphasis was placed on involving New Jersey Department of Transportation engineering staff throughout the different phases of the work.

After a brief review of research reports and preliminary discussions with New Jersey Department of Transportation personnel, an initial questionnaire was designed. This questionnaire was intended to determine a consensus of the needs and priorities that managers and professionals place on highway delineation. The responses to this initial survey guided much of the subsequent research work and established priorities for environmental and geometric situations that might require special delineation attention.

From the priority of needs established by the first questionnaire, more specific questions, called "issues", were developed. Issue identification was a critical step in the research project and issues are generally categorized by the type of delineation technique. In a second questionnaire,

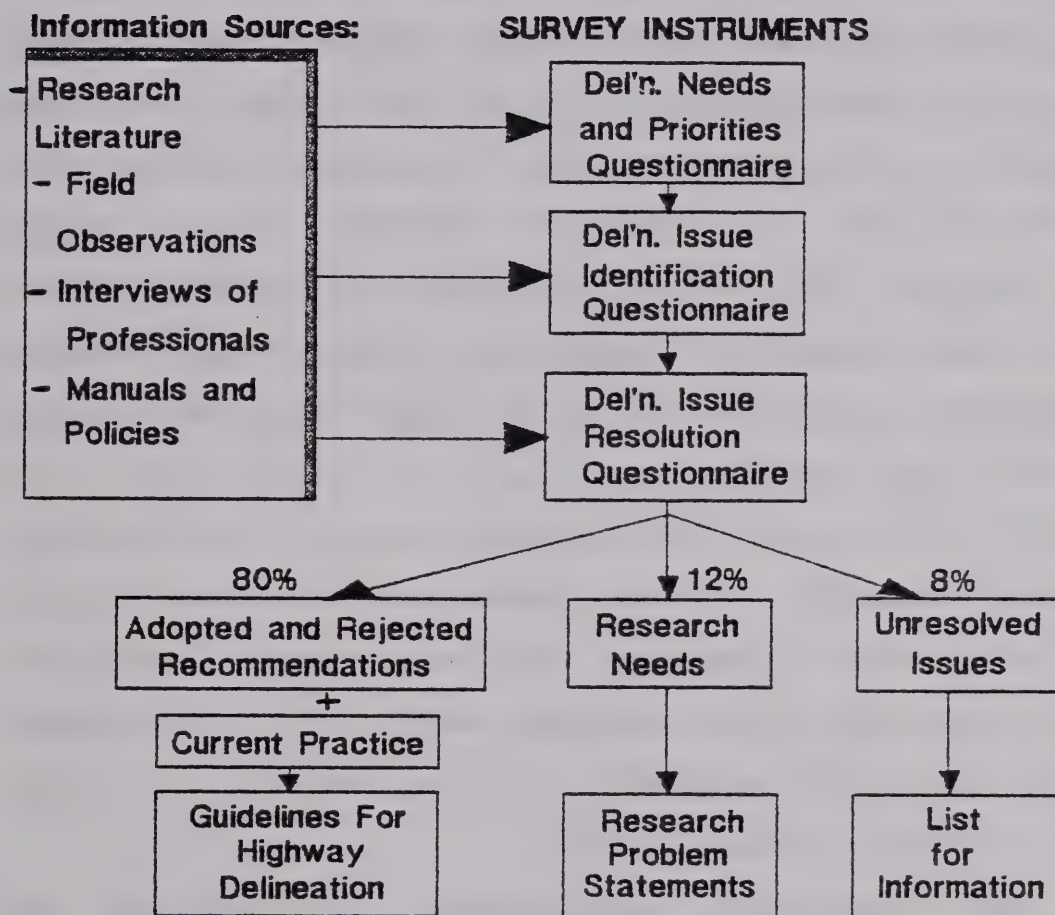


FIGURE 1 - PROCEDURE

called the Issue Identification Questionnaire, respondents were asked to decide if a statement was an issue and to rate its importance. The issues from the second questionnaire were divided into sub-issues to address each technical aspect. Possible answers to specific delineation questions were included in a third questionnaire, called the Issue Resolution Questionnaire. The questionnaire was structured similar to the format used by the consensus-based committee ballots of the American Society for Testing and Materials (ASTM). Many acceptable resolutions to issues were found directly from the issue resolution questionnaire. A copy of each questionnaire can be found in the appendix.

A few of the issues from the issue resolution questionnaire had unclear responses. These issues were discussed at group meetings with people concerned with the issues. The extra information presented at the meetings and the ability to discuss the issues face to face enabled the meeting participants to make consensus decisions on these issues.

From the resolution questionnaire and meetings, the dispositions of the issues were determined. There are four categories of issue disposition: 1) adopt a recommendation for resolving a delineation issue, 2) reject a recommendation for resolving an issue 3) define research needs for resolving an issue, and 4) unresolved issues. The adopted and rejected recommendations on delineation practice combined together with delineation practices not at issue formed the "Guidelines for Highway Delineation," the main technical output of the project.

The research needs that were defined were submitted as research problem statements for consideration by the Division of Research and Demonstration.

The unresolved issues were listed for informational purposes. This report makes no recommendations on delineation practice in areas where issues concerning technical improvement could not be resolved. Future developments may affect these areas.

The consensus procedure used in this project to resolve issues helped speed up technical implementation of research results. Similar methods could be used by other states and other organizations for implementing new technology.

RESULTS

A. DELINEATION NEEDS

1. General Delineation Needs

From the Delineation Priorities Questionnaire, the following were prioritized by New Jersey Department of Transportation professionals as the geometric situations and environmental conditions that warrant extra attention: 1) everyone stressed the need for improving nighttime visibility, 2) rainy or wet nights had the highest priority followed by 3) foggy nights, and 4) exit, entry and gore areas.

2. Roadway Delineation Needs

From the priorities questionnaire, increasing roadway delineation was prominently selected for improving nighttime driving conditions.

New Jersey Department of Transportation professionals prioritized the need for roadway delineation as follows: 1) pavement markings (paint, epoxy, etc.), 2) snowplowable raised pavement markers, and 3) permanent striping tapes.

3. Roadside Delineation Needs

New Jersey Department of Transportation professionals and managers rated increasing roadside delineation as an important way of improving nighttime visibility, with post mounted delineators and chevron signs being mentioned most frequently.

4. Median Delineation Needs

From the Delineation Priorities Questionnaire, for median delineation of divided highways, respondents rated 1) snowplowable raised pavement markers as a first priority, with 2) center barrier delineators, 3) post mounted delineators and 4) guiderail delineators following.

Post mounted and guiderail mounted delineators and raised pavement markers may be used as forms of median delineation where center barrier is not provided.

5. Work Zone Delineation Needs

From the Delineation Priorities Questionnaire, respondents rated 1) Barrels, 2) barricades (Type I, II and III), 3) temporary tape, and 4) cones in that order for temporary delineation in construction zones on highways.

Also, temporary raised pavement markers (TRPMs) may be used for roadway delineation in place of paint or tape.

B. GUIDELINES FOR HIGHWAY DELINEATION

1. The "Guidelines For Highway Delineation" are shown separately on the next page.

GUIDELINES FOR HIGHWAY DELINEATION

1. Foreword

Delineation practice by the New Jersey Department of Transportation follows the Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD provides general information on highway delineation. The Guidelines for Highway Delineation supplement the MUTCD with information determined by consensus. The Guidelines contain decision making and technical information agreed to through a consensus by groups of key New Jersey Department of Transportation professionals and managers. The Guidelines: 1) supplement minimum MUTCD requirements, and 2) address implementation details.

The guidelines represent the opinions of selected experts in the New Jersey Department of Transportation, and the following definition applies throughout: The word "should" refers to the consensus of a committee of professionals and managers involved with delineation activities.

2. Pavement Striping

- a. Pavement stripes should be applied with a 4-inch width.
- b. Skip lines should be used on freeway ramp weaving areas rather than dotted lines.
- c. Special striping to show turning paths in intersections should not normally be used. They might be considered for use when traffic patterns show a need.

- d. Long life markings should be installed on limited access highways, other roads with more than 25,000 AADT (moderate traffic volume), and other sites identified by Regional Maintenance Engineers. Long life striping should be installed as part of roadway reconstruction projects and major resurfacing jobs.
- e. Grinding is the best method available for removing traffic stripes. However, due to the expense, inconvenience, and traffic disruption of the grinding operation, it should be avoided as much as possible.
- f. The installation of short lengths of long life striping should be avoided due to the difficulties of maintaining short sections of different types of striping.

3. Snowplowable Raised Pavement Markers (SRPMs)

- a. Yellow markers should supplement yellow lines and clear markers should supplement white lines.
- b. Markers used for motorist guidance should use a non-reflective side facing wrong way motorists and not a red reflective side.
- c. Markers should be placed in line with and in the gap of skip lane lines. Markers should be offset from solid edge lines. Markers should be offset to the traffic side of left edge lines and placed between double yellow center lines.

- d. Markers should not normally be used to delineate the proper direction of travel where there is no painted line to supplement, unless the location of where a well-placed line would go to avoid dirty, untraveled areas can be established first.
- e. Double solid yellow center lines and median solid edge lines should be supplemented with markers every 80 feet.
- f. Lane skip lines should be supplemented with markers every 80 feet.
- g. Right solid edge lines should not normally be supplemented with markers. Exceptions should be made where it is important that drivers see the exact location of the road edge approaching and in areas where there are: 1) fixed obstacles or difficult traveling surfaces exceptionally close to the edge of the roadway, such as guardrail, trees, poles and bridge rails, ditches; and 2) lane drops and road width reductions. At these locations, the edge line should be supplemented with markers every 20 feet including a reasonable approach treatment.
- h. At exits, lane drop exits, and splits, skip lines upstream of gores should be supplemented by markers every 40 feet, and painted gores should be supplemented by markers every 20 feet. Painted exit gores shorter than 80 feet should be supplemented with markers every 10 feet.

- i. The maximum spacing of markers where three or more degrees of curvature are encountered should be 40 ft., and where 15 or more degrees of curvature are encountered, the maximum spacing should be 20 feet. Where curves are encountered, good engineering judgement should prevail over spacing guidelines, where necessary, since other factors may have to be taken into account.
- j. Approaches to signalized intersections should not be supplemented by markers at other than the spacing required for the through movement. Solid channelizing lines at signalized intersections should be supplemented by markers every 20 feet.
- k. The presence of passing, no passing, or combinations of passing and no passing situations should be not be differentiated by special spacings of SRPMs or other unusual SRPM treatments.
- l. Concrete joints should not be straddled by an installation of a SRPM, unless it is judged by the Bureau of Traffic Engineering that the lane narrowing effect of offsetting SRPM's from joints would be undesirable.
- m. Approaches to unsignalized intersections should not be supplemented by markers at other than the spacing required for the through movement.
- n. SRPM's should not be used on interchange ramps.
- o. Special use lanes, such as continuous center left turn lanes, should not be identified by special SRPM spacings.

- p. The present 6-inch space between double solid yellow center lines should be continued as an aid in avoiding painted SRPM reflectors. An 8-inch space should not be used.
- q. The device used on painting trucks that interrupts the striping operation to avoid painting SRPMs should be used continuously and any problems with the device should be overcome as they occur.
- r. SRPMs should be installed according to existing guidelines on both lighted and unlighted roadways.
- s. New system wide installations of SRPMs should not be continued without making technical changes in the SRPM program to address durability and cost considerations. SRPM installations should be continued at locations determined by the Bureau of Traffic Engineering and Safety Programs based on their analyses of accident data.
- t. If durability and cost considerations can be resolved, install Snowplowable Raised Pavement Markers on all freeways and interstate highways, and install SRPMs on State highways at locations determined by the Bureau of Traffic Engineering and Safety Programs based on their analyses of accident data, etc.
- u. Construction adhesive should be used for replacing the reflectors in the castings.
- v. Department Quality Assurance inspections of SRPM casting and reflector installations should be done within one month after installation.

w. Existing SRPM installations should be inspected annually until experience is developed about wear rates at specific sites. Then, appropriate longer inspection intervals should be established that vary by road section. AADT per lane should be used as an interim measure relating to SRPM reflector wear.

4. Post/Guiderail Mounted Roadside Delineators

- a. Because guiderails along the roadside are a reliable structure on which to mount roadside delineators, delineators should be mounted on guiderail whenever it is within the lateral distance from the roadway or shoulder edge where post mounted delineators would normally be placed (2 to 8 feet).
- b. Delineators mounted on guiderails should have the same spacing, height, and appearance as delineators mounted on posts.
- c. When used on tangent roadway sections, roadside delineators should be mounted at 200-ft. intervals, in accordance with the typical plan CD-47 in the NJDOT Standard Roadway Construction Details. Spacing on curves should follow MUTCD standard spacing recommendations as found in Table III-1 of the Manual, 1988 edition.
- d. Consideration should be made to include delineators on bridge railing and right side concrete barriers whenever delineators are installed on the guiderail upstream of the railing or barrier.

e. Rigid and flexible posts may be used for post mounted delineators. Flexible posts may be used under the following conditions:

i. To replace damaged posts on short radius curves (R=150) with high approach speeds.

ii. Where the expected life of right post mounted delineators is less than one year.

iii. Areas where metal posts have less than a 25 percent survival rate.

f. Chevron alignment signs should be used to supplement post mounted delineators as determined by Traffic Engineering and Safety Programs.

g. Post mounted delineators are required on interstate roads and on freeway ramps. Post mounted delineators should be used on other classes of roads as determined by Traffic Engineering and Safety Programs.

h. As stated in section 3D-4 of the 1988 edition of the MUTCD: "Roadside delineators shall be optional on tangent sections of expressway and freeway roadways where SRPMs are used.

5. Median Delineation

a. Concrete median barriers should be delineated with acrylic cube corner reflectors mounted on top of the barrier.

- b. Spacing of the concrete median barrier reflectors should be 80-ft. on tangent roadway sections and 40-ft. on curves.
- c. Concrete barriers dividing local from express traffic lanes should also be delineated.
- d. Grass median areas should be delineated with post mounted delineators when determined by Traffic Engineering.
- e. When guiderail is present within 2 to 8 feet of shoulder edge in median areas, delineators should be mounted on the guiderail rather than on separate posts.
- f. Because guiderails along the roadside are a reliable structure on which to mount roadside delineators, delineators should be mounted on guiderail whenever it is within the lateral distance from the roadway or shoulder edge where post mounted delineators would normally be placed (2 to 8 feet).
- g. Delineators mounted on guiderails should have the same spacing, height, and appearance as delineators mounted on posts.
- h. When used on tangent roadway sections, roadside delineators should be mounted at 200-ft. intervals, in accordance with the typical plan CD-47 in the NJDOT Standard Roadway Construction Details. Spacing on curves should follow MUTCD standard spacing recommendations as found in Table III-1 of the Manual, 1988 edition.

6. Work Zone Channelizing Devices

- a. Type III Barricades should be used as channelizers in taper areas of lane closures for construction zones.
- b. The tall panel channelizers mounted on drums, as recommended by Davis(6), may be used in certain taper situations as determined by Traffic Engineering.
- c. Drums should be used as channelizers for indicating lane closures outside of taper areas in construction zones.
- d. Cones should be used for lane closures for maintenance activities which generally last less than one day.
- e. The use of cones for nighttime lane closures should be avoided, larger channelizers such as drums should be used.
- f. Channelizers should be spaced at the speed limit in feet for lane closures other than in taper areas.
- g. Channelizer layouts and spacing details should conform to the NJDOT Traffic Control Plan for various closure types including ramp closures.

7. Temporary Concrete Barrier Delineation

- a. 6" x 12" reflective sheeting panels should be attached to the tops of the barriers at 100-ft. intervals on tangents and 50-ft. on curves.

8. Work Zone Pavement Striping

- a. Where longer term diversions or realignment of traffic lanes through active work areas is necessary, temporary pavement marking tape should be used to provide pavement markings.
- b. In long term, work zones of considerable length, paint may be used to provide pavement markings.

- c. Abbreviated pavement markings (4 ft. stripe with 36 ft. gap) should be used on new pavement; This would apply only to permanent alignments without lane closures.
- d. Due to removal problems with pavement marking tape temporary raised pavement markers should be used on grooved bridge decks as a substitute for paint or tape, unless snowplowing of the work zone is expected.

9. Temporary Raised Pavement Markers

- a. When used as a substitute for solid pavement stripes, TRPMs should be spaced at 5-ft. intervals ($N/8$, where N is the stripe cycle length; 40 ft. in New Jersey) with retroreflective units every 20-ft. as stated in the MUTCD in section 3B-16, 1988 edition.
- b. Consideration should be given to providing a transition area both upstream and downstream of grooved bridge decks in construction zones where TRPMs are used for roadway delineation.

C. MANAGEMENT RECOMMENDATIONS

1. The New Jersey Department of Transportation's long life pavement marking committee should continue its ongoing demonstrations and implementation efforts.
2. The research project "SRPM Wear and Improvement" should continue to investigate reflector adhesives.
3. The research project "SRPM Wear and Improvement" should continue to investigate faster casting adhesives.
4. New SRPM casting designs should be evaluated as they become available.
5. The Bureau of Materials, with advice from the Division of Research and Demonstration, should investigate new reflector testing methods with the goal of improving reflector performance in the field.
6. Continuing effort is needed to ensure the reliable operation of the paint skip device.
7. As a probable cause of severe damage to the SRPM reflectors, snowplow wheels should be replaced with shoes as extensively as possible considering equipment compatibility. After converting the snow plow equipment, which has been shown to be a major cause of premature reflector damage, (J. Semler, New Jersey Department of Transportation, Unpublished Report, 1989), excessive SRPM wear should no longer be a reason for postponing new SRPM installations.
8. Demonstrations of reflectorized treatments for median barrier glare screens should be continued.

9. In accordance with existing research results, Davis (5), a list of specific manufacturer's adhesives that work with specific TRPM types should be developed and included in the NJDOT specifications.
10. Specifications for the tall panel on barrel channelizers studied in a research project by Davis (7), should be developed and included in NJDOT standard specifications to ease the procurement and use of the devices when use of the devices is desired.

D. UNRESOLVED ISSUES

There were several items that weren't resolved. Many people involved with this study felt that delineation maintenance needs to be improved. Because no technical needs were identified, research studies were not seen as being able to help the situation. The unresolved issues are as follows:

1. Will guiderail mounted delineators be maintained if they are installed?
2. What is the tolerable statewide average rate of wear before money spent on SRPM's is considered "wasted?"
3. Are post mounted delineators and median barrier delineators maintained adequately after they are installed?

PROJECT EVALUATION AND DISCUSSION

One weakness of the project was the uncertainty of how and why people responded the way they did to the questionnaires and surveys. Did subordinates respond truthfully, or with answers pre-programmed from their supervisors? Did respondents choose "DON'T KNOW" appropriately, or make up answers? There was approximately a 90% return rate to the questionnaire surveys. Because the questionnaire results were carefully analyzed and distributed in printed form and at meetings, errors from faulty responses were minimized.

Eleven issues were selected for discussion at meetings; thirteen issues were eventually affected by the meetings' outcome. The committee meetings held at the end of the project were an important part of the process.

Finally, 47 out of the 59 original issues achieved a technical decision to implement or reject an action. Seven issues were proposed for research or demonstrations. Five issues remained unresolved but these were distributed to operations managers for informational purposes (they are listed under item D above).

TABLE 1
INCREASE OF DEVICE ACCEPTANCE
FROM INCREASED COMMITTEE ACTIVITY

<u>Device-Treatment</u>	<u>Group No.</u>	<u>Major** Application</u>	<u>Minor** Application</u>	<u>No Application</u>	<u>Don't Know**</u>
Center Barrier	1	58	42	0	0
Delineators for	2	78	22	0	0
Median Delineation	4	80	20	0	0
Center Barrier	1	44	40	0	15
Delineators for	2	67	33	0	0
Temporary Delineation	4	80	20	0	0
Guiderail Reflectors	1	26	51	2	9
for Roadside	5	67	33	0	0
Delineation					
Guiderail Reflectors	1	26	58	2	11
for Median	5	50	50	0	0
Delineation					
Temporary Raised	1	55	31	6	7
Pavement Markers	2	56	11	11	22
in Construction	3	60	40	0	10
Zones	4	60	20	0	20
Tall Panels on	1	15	36	2	42
Barrels for	3	20	40	0	40
Temporary	4	60	20	0	20
Delineation					

** This means the percentage of respondents who thought a delineation device would have application on New Jersey Highways in the next 15-20 years, as rated on the following scale: Major Application, Minor Application, No Application Don't Know.

<u>Group No.</u>	<u>Members</u>	<u>No. of Comments</u>
1	55	All respondents
2	9	Familiar with J. Powers' research on Center Barrier Delineation 1986.
3	10	Members of T. Davis' Committee for Temporary Delineation in Construction Zones 1984.
4	5	Members of T. Davis' Committee for Temporary Delineation in Construction Zones 1986.
5	6	Members of J. Campi's Committee for Guiderail Delineation 1985.

TABLE 2
DISPOSITION OF ISSUES

	<u>ACTION</u>	<u>NO ACTION</u>	<u>RESEARCH</u>	<u>UNRESOLVED</u>
Before Meetings	31	16	6	6
After Meetings	31 (6)	16 (6)	7 (5)	5 (1)
After %	53%	27%	12%	8%

The numbers in parentheses indicate the issues that were affected by the meetings.

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REFERENCES

1. Freedman, M., Noticeability Requirements for Delineation on Non-Illuminated Highways, Report No. FHWA-RD-88-028, Federal Highway Administration, July 1988.
2. Bali, S.G., H. McGee, and J. Taylor, State-of-the-Art on Roadway Delineation Systems, report No. FHWA-76-53-13, Federal Highway Administration, 1976.
3. Vanstram, R.C. and Landen, J.C., The Dark Side of Driving, Transportation Quarterly, Volume 30, No. 4, October 1984.
4. Dale, J.M., Pavement Markings: Materials and Applications for Extended Service Life, NCHRP Synthesis No. 138, Transportation Research Board, June 1988.
5. Standard Guide for Understanding the Properties of High Visibility Materials for Individual Safety, American Society for Testing and Materials, F923-85, Annual Book of ASTM Standards, Vol. 14.02.
6. Davis, T.D., Evaluation of Temporary Day-Night Visible Raised Pavement Marker Adequacy, Report No. FHWA/NJ-88-004-7729, March 1989.
7. Davis, T.D., Construction Zone Safety and Delineation, Report No. FHWA-NJ-88-005-7768, New Jersey Department of Transportation, February 1983.

APPENDIX A

SUMMARY OF DELINEATION STUDIES COMPLETED BY THE
NEW JERSEY DEPARTMENT OF TRANSPORTATION

STRIPING

Keck, W.D. and A.W. Roberts, The Effect of Dotted Extended Lane Lines on Right, Single Deceleration Lane Use, NJDOT Report No. 77-011-7714, January 1978.

This study found that using dotted lines on freeway exits caused drivers to move into the deceleration lane sooner than without the dotted lines.

Batz, T.M., Evaluation of New Passing Zone Gore Design, Report No. FHWA/NJ-89-004-7733, August 1988.

It was found from this study that using a painted gore to channelize traffic into the right lane at the beginning of passing zones reduced illegal and erratic maneuvers and increased passing efficiency at passing zones longer than one-half mile.

Szalaj, W.M., Effect of Width on Edge Line Life, Report No. FHWA-NJ-89-003-7728, 1989.

This effort determined that 6-inch wide edge lines wear out as fast as 4-inch lines.

RAISED PAVEMENT MARKERS

Jagannath, M.V. and A.W. Roberts, Evaluation of Snowplowable Raised Pavement Markers in New Jersey, Report No. FHWA-NJ-RD-77-004-7708, November 1976.

This research found that SRPM castings are resistant to snowplowing, attributes SRPM reflector damage to both snowplowing and traffic, and provides cost estimates for marker installation and maintenance.

Graf C.R. and A.W. Roberts, Snowplowable Raised Pavement Markers at Hazardous Locations in New Jersey. Report No. FHWA/NJ-80-011-4668, September 1979.

The major findings of this study are: 1) one year old markers could be seen for 1400 feet, 2) after one year, 10% of reflectors needed replacement but no castings were damaged, 3) spacing should vary according to curvature, and 4) cost per marker was \$20 to \$26.

Mullowney, W.L., Effect of Snowplowable Raised Pavement Markers on Traffic Performance, Report No. FHWA/NJ-83-001-7769, June 1982.

This study found that the use of SRPM's reduced erratic maneuvers with traffic volumes up to 500 veh/hr/lane and reduced erratic maneuvers during rainy nighttime conditions, and that markers should be spaced 20 feet on gores and 40 feet on lane and edge lines.

WORK ZONE DELINEATION

Davis, T.D., Construction Zone Safety and Delineation, Report No. FHWA-NJ-83-005-7768, February 1983.

The Construction Zone Delineation Study was conducted to find methods for improving delineation in construction zones

with long term overnight closures or diversions. The need for improved delineation was established through two means: 1) a committee of traffic, construction, design, research and specification engineers, and 2) positive guidance, a technique that develops highway information system improvements from the driver's viewpoint. Once the need for improved delineation was established, delineation concepts were developed and tested in actual construction zones and evaluated for effects on traffic performance and driver visibility. The experiments showed that: 1) the use of 5" x 10" yellow high intensity reflectors as a replacement for steady burn lights did not result in any change in mean speed and speed variance or the proportions of vehicles using the lane adjacent to the reflectors; 2) tall vertical reflectorized panels as a replacement for Type III barricades resulted in a decrease in nighttime lane encroachments while mean speeds or speed variances remained unchanged; 3) removable traffic tape was easy to install and easy to remove and proved to be problem free while down and yet was as visible as paint; 4) raised pavement markers as a paint supplement resulted in a reduction of lane changes and encroachments, both day and night; 5) raised pavement markers as a paint replacement resulted in a reduction in lane changes day and night and lane encroachments at night, though a durable marker still needs to be found; 6) the butyl adhesive with primer was still the most durable method of adhering markers to the pavement, though simpler techniques were tried.

Davis, T.D., Evaluation of Temporary Day-Night Visible Raised Pavement Marker Adequacy, Report No. FHWA/NJ-88-004-7729, March 1989.

This study determined that temporary raised pavement markers (TRPM's) should have a streamlined profile, a cube corner or multiple glass lens reflector, and both casing and reflector exposed to the driver. Also, certain hot melt adhesives for TRPM's were found to have advantages over the butyl pad adhesive system.

Davis, T.D., Signs on Breakaway Barricades, Report No. FHWA-NJ-90-007-7410, April 1990.

This study tested aluminum and vinyl signs mounted on breakaway barricades for use in work zones.

Mullowney, W.L. and J. Campi, Investigation of SRPM Reflector Damage Caused by Snowplow Castor Wheels in New Jersey, 1986.

This study generated an estimate of the amount of reflector damage attributable to snowplow wheels by comparing SRPM installations where wheels were used to installations where snowplow shoes were used. The yearly damage was estimated at \$21,000 and is considered too low to require a change from wheels to shoes.

An analysis of data from nearby states resulted in the conclusion that New Jersey is not experiencing higher damage rates to reflectors, as previously thought.

ROADSIDE AND MEDIAN DELINEATION

Mullowney, W.L., Center Barrier Visibility Study, Report No. FHWA-NJ-80-002-7710, January 1978.

The recommendations from this study for delineating median barriers include: 1) three inch cube corner reflectors placed on top of the barrier, 2) a flexible mount attached with a butyl pad and stud, 3) 80 feet spacing on tangents and 40 feet on curves.

Mullowney, W.L., New Jersey Concrete Median Barrier Delineation, Report No. FHWA/NJ-80/007, October 1979.

This is a follow up study to the 1978 Center Barrier Visibility Study and produced an improved specification for mounting methods and materials

Powers, J.C., Center Barrier Delineator Spacing, Report No. FHWA/NJ-88-013-7714, April 1988.

This study found that 160 feet spacing is adequate for delineating straight and level roads, 80 feet is required for moderate vertical curves, and 40 feet for a 2° or greater curvature, and recommended spacings of 80 and 40 feet be implemented.

Campi, J., Guiderail Delineation, Report No FHWA/NJ-87-006-7751, February 1990.

This study investigated mounting methods and styles of reflectors for roadside delineators mounted on guiderails. A flexible post with reflective sheeting similar to flexible post delineators was recommended.

Lovett, F., Flexible Delineator Posts, 1985.

This study found that certain flexible posts may be used for replacement of steel posts at high impact areas, that maintenance yards responsible for grass cutting also replace the posts, and that NJ type II reflective sheeting only be used and meet all MUTCD dimensional requirements.

Smith, M.J. and K.R. Desfosse, Guiderail Visibility Needs Analysis - Interim Report, September 1984.

The analysis found that guiderail delineation could provide increased hazard detectability and recognition and improved roadway alignment information. Also, the probability of a positive cost benefit from guiderail accident reduction was discussed.

APPENDIX B

GUIDELINES FOR HIGHWAY DELINEATION:
LITERATURE SYNTHESIS

GUIDELINES FOR HIGHWAY DELINEATION:
LITERATURE SYNTHESIS

BY

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THE CONTENTS OF THIS REPORT REFLECT THE VIEWS OF THE
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16. Abstract This is a review and synthesis of research literature and manuals concerned with highway delineation. The purpose is to collect and present delineation research results and standards in one place for developing delineation guidelines. The report covers permanent delineation and work zone delineation. It was found that pavement markings or markers are needed that can provide wet weather, nighttime delineation. Roadside (often post mounted) reflectorization is also important for providing longer range guidance and effective delineation in wet and snowy weather. Work zone delineation should be clear and should overwhelm old pavement markings and should be maintained frequently.			
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SUMMARY AND CONCLUSIONS

Many research studies have been done on the subject of roadway delineation, ranging from simple retroreflector demonstrations to comprehensive studies of complete delineation systems. The results of these studies are not always in agreement. This synthesis records and compares the various research results available. The general findings from this effort are: 1) Pavement stripes' visibility is limited at night in wet weather; roadway delineation that is effective in wet weather is needed. 2) Roadside delineation, such as post mounted delineators, improves traffic performance, provides delineation during wet weather, and provides guidance when roads are snow covered. 3) Substandard geometric conditions in construction zones require specially designed and maintained delineation. Research was sparse in the areas of visibility standards, combinations of delineation, and the effect of these items on driver performance and safety.

RECOMMENDATIONS

Highway agencies should provide drivers with delineation that is effective day and night during inclement weather. Nighttime driving on wet roadways has special delineation requirements which could be met by using raised pavement markers.

Roadside post mounted delineators should also be used because they provide longer range guidance, improve traffic performance, and are effective in wet and snowy weather.

Work zone traffic control delineation should be clear and should overwhelm old pavement markings, while being designed to be as comparable as possible to regular traffic control. Work zone delineation should be maintained to a high standard. Drive-through checks should be made during both day and night.

In addition to the results of the existing research reports, several areas of delineation lacked research activity. Little information was available on how combinations of delineation treatment affect traffic safety. Few studies have been done on specific visibility standards for delineation. For example, what luminous intensity should retroreflectors emit? How can delineators be measured to compare their performance to required specifications? What is the effect on driver performance of deferred maintenance of delineation? Studies in these areas would help implementation by defining delineation needs and determining performance standards.

INTRODUCTION

This is a report on research literature concerned with roadway delineation.

This synthesis was done as part of a research project called "Guidelines for Highway Delineation," which is different from most other research projects. The project synthesizes available delineation research results, along with the expert opinions of Department professionals into a guideline covering various types of roadway delineation. The objectives of the study are:

1. to select the delineation devices and methods that are ready to use and determine the optimal uses for such devices in different geometric and environmental situations, and
2. to determine which delineation systems are not ready to use but have promising future potential and prepare research problem statements where interest in further investigation is determined.

Besides literature, field studies, questionnaire surveys, and interviews were used to develop the guidelines. The guidelines are to be used as references for the Department of Transportation for design activities, traffic engineering, highway maintenance, etc.

This synthesis is one way of identifying issues for the project and also helped with the formulation of possible solutions to these issues. This report is a method of identifying problems with the use of different delineation treatments and may help resolve previously identified problems. Most studies investigate a single type of delineator in order to simplify evaluation activities, and then either recommend the treatment under study or don't recommend it. Some research efforts evaluate combinations of delineation treatments. This report will attempt to compare and clarify the relationships between the many past research studies.

A. Purposes of Delineation

The purpose of delineation is to show drivers road alignment and the available lanes on the roadway so they can select the appropriate safe speed and travel path for the roadway and

environmental conditions. Delineation provides the visual information needed by the driver to select the proper speed and travel path by providing guidance, lateral control, and hazard warning (1,2). Delineation treatments also provide regulatory information by color or by configuration; one research study found delineation color coding ineffective (3). Markings on the pavement provide "near" delineation for control while post mounted reflectors provide "far" delineation for guidance (3). Object markers are used to show traffic islands, medians, bridge piers and abutments, handrails, rails, headwalls, etc. (1). Adequate contrast is necessary to make these objects visible (4). Traffic cones are sometimes used for traffic control outside of construction zones (5).

B. Methods of Measuring Delineation Effectiveness

Accident rates, traffic performance, and opinion surveys are measures of delineation effectiveness (6). The accident rate can be used as a measure of delineation system effectiveness, but due to the relatively low number of accidents, statistical comparisons of delineation treatments using accident data are difficult to make (6). Traffic performance measures such as lateral placement variance and erratic maneuvers are often used in place of accident data to try to predict delineation effectiveness in preventing accidents (6). The probability of a vehicle leaving the lane can be used as a measure for comparing delineation treatments (7,8). Vehicle lateral placement and especially the placement variance are sensitive measures of traffic

performance (6). Encroachment measures are somewhat less sensitive but are more meaningful in terms of the intention of the marking treatment. Methods have been used for filming delineation for later viewing and evaluation by designated groups of people (9). If factors other than accidents, such as driver comfort, are being evaluated, the preference for evaluation methods should change (6).

C. Roadway Characteristics and Delineation

The delineation system selected should relate to the roadway and traffic conditions. Delineation should be upgraded until the actual curve detection distance equals or exceeds the required detection distance which is based on curve geometry, traffic velocity, driver ability and other factors (10). Freedman found that with simple roadway geometry and operations, complex roadside environments decrease the need for delineation, however, if traffic operations are demanding, along with a complex environment, higher-level delineation treatments are appropriate (11). Capelle, in a 1978 FHWA synthesis (12), mentions that elaborate delineation systems provide superior performance but may not be economic. Dale (13), brings up the paradox that the Interstate System receives the most attention with regard to delineation and Interstates are the best marked roads, but a majority of fatalities occur on less well marked rural two lane roads. Some argue that more expensive investments, such as Interstate Highways, justify the best marking and safety treatments available. Walton (14)

identified roadway characteristics that affect visual research needs. Construction details such as joints, pavement edges, rail, rumble strips, and contrasted shoulders all provide unintentional delineation (15). Natural roadside features also provide delineation (15). These cues are more important at night when roads are wet (16). Roadway designers must consider the guidance drivers receive from visual cues other than striping, such as joints, shoulders, curbs, driveways, shrubs, and trees. One study (3) claims that curbs can be a hazard and that they don't provide significant delineation. The New Jersey DOT Roadway Design Manual states that curbs are not to be used on freeway ramps except at connections with local street curbs or when needed to control drainage (17).

D. Visibility of Delineation

The driving environment is constantly changing and drivers rely heavily on delineation at night and in inclement weather. Climate, geometry, pavement type and condition, and traffic all influence delineation selection (1). Increased eye height above delineation improves curvature perception and lateral sensitivity (18,19). Allen lists rain, snow, fog, mist, sun and sky glare, atmospheric boil, and mirage effects as daytime visibility hazards, and lack of street lights, low reflectance pavement, improper reflectorization, rain, fog, and insufficient headlights as nighttime visual hazards (4). Sudden changes in luminance levels may cause

losses in visibility (20). Delineation should have adequate contrast and continuity to be effective (15). Potters Industries (21) claims that extra delineation, such as stripes, raised pavement markers, Post Mounted Delineators (PMD's) reduces night myopia - the tendency of drivers to focus their eyes on the windshield rather than the roadway. Drivers find night driving more difficult and believe it to be more hazardous than daytime driving (22). Drivers rely almost exclusively on delineation at night (3). Night driving is two times more dangerous than daytime driving and nighttime accidents are increasing as a proportion of accident totals (23,24). Inadequate night visibility is the prime suspect in nighttime fatalities (13). Nighttime accidents increased during 1975 to 1982 and may be due to poor visibility and fatigue (23). One study says that two seconds of delineation preview distance is needed in extreme situations such as fog, rain, or headlight glare, and three seconds are desirable (250 ft. at 55 mph) (11). Another study found that a delineation visibility distance of 450 ft. (corresponding to a 5 second preview time at 60 mph) is necessary (25). John M. Dale, in his June 1988 NCHRP synthesis, contends that 2.5 seconds are needed for a driver to comprehend and act on a stimulus (13).

Rain and other adverse weather conditions degrade roadway marking visibility (1) and contribute to a higher risk of having an accident in rainy weather (26). Dynamically changing wetness conditions make wet-pavement reflectance measurement difficult (27). Dejaiffe reported

that using a video camera to record nighttime delineation performance enabled objective, permanently recorded comparisons but did not allow quantitative data collection (28). Dejaiffe proposes a laser illuminated retro-reflectometer which has the following advantages: 1) the device measures reflectance relative to the known illuminance of the laser and calculates the coefficient of reflectance directly, 2) it is not affected by ambient light, 3) it allows measurement under prevailing environmental conditions such as rain, and 4) it allows determination of contrast. A metered water system using a tent and a net to apply a definite quantity of water to a road was developed in the Federal Republic of Germany (28). Using this system, researchers made readings using a luxmeter and a telephotometer to compare wet vs. dry reflectance over a three year wear period. They found that the best lines retained 50% of the dry coefficient of reflectance when wet. Dejaiffe (28) reports that an indoor laboratory equipped with pavement, sprays, and special lighting can compare striping at distances up to 150 ft.

E. Maintenance of Delineation

There are two types of maintenance: emergency and routine (1). Routine maintenance should be scheduled if inspections show a need (1). An agency assumes a responsibility for keeping markings in good condition once it marks a road (13).

Recent developments in the area of delineation maintenance include the ability to measure marking retro-reflectivity to determine replacement needs. Methods are also being developed to measure marking performance from moving vehicles. Several researchers have studied the minimum levels of retro-reflectivity needed by drivers for guidance at night. These are briefly discussed here and also throughout this report. In a practical sense, a minimum retro-reflectivity level is a level that will ensure the line will not become unsatisfactory for visual guidance before it is next inspected and can be scheduled and remarked. This is becoming of greater importance as durable marking materials replace paint. Freedman (11) states that to maintain the required contrast level of pavement markings, a retro-reflectivity of 64 to 127 mcd/m²/lux is needed for dry roadways. Also, 13 to 26 mcd/m²/lux should be maintained for wet roadways. Freedman goes on to say that if these retro-reflectivity levels cannot be maintained, supplemental delineation such as RPMS may be appropriate. Freedman calls for further research to better define the luminance and contrast levels that will provide the required 2 to 4 seconds of delineation preview distance.

Ethan and Woltman (29) report that a minimum specific luminance for striping should be 100 mcd/m²/lux. In addition, the minimum required stripe contrast with the road surface depends on a luminance that exceeds 3 times the road surface luminance.

This new information is leading toward better specifications for delineation performance. The use of retro-reflectance measurement techniques and quantitative requirements for delineation performance may improve driver guidance by better directing maintenance work to areas of marginal visibility.

Additional information on delineation maintenance is presented in the sections of this report on striping, Raised Pavement Markers, and Post Mounted Delineators.

PERMANENT DELINEATION

A. ON-ROADWAY DELINEATION

1. Striping

a. Warrants

The most common form of permanent delineation is pavement striping. There have been a number of studies of the usefulness of pavement striping compared to unmarked pavement. One research report (15) recommends center lines for roads wide enough for two way traffic, while another (30) found that center line markings are effective in preventing accidents on rural roads if AADT is greater than 1000. Other research determined that edgelines improve lateral stability (15), and improve orientation through peripheral view, which allows drivers more time to scan the road ahead (21). Edge lines have been found to reduce lateral placement variance and improve the centering of vehicles in traffic lanes, and so roadways 22 ft. wide and wider should have edgelines (3,6). The edgelines of through

highway lanes should be delineated near the areas of merges and ramp termini (6).

b. Width

Investigations made into the optimum width of pavement stripes have found that the widely used 4" wide stripes are the best. Two separate studies found that edgelines 8" wide do not improve driver performance compared to 4" lines (31,32), and do not affect run-off-the-road accidents (33). Stripes 4" wide are as good as 6" wide (3). NCHRP 130 (6) found that 4 in. wide lines are optimum. It was theorized that wider edgelines would reduce tire encroachments on the surface of the line which might affect line wear (34). However, retro-reflectance measurements by Szalaj (34) proved 6 and 8 in. wide edge lines do not have a longer useful life than standard lines and require repainting as often as four-inch stripes. A comprehensive study done for the FHWA (35) confirmed from subjective ratings that 8 in. wide edgelines do not have longer service lives than 4 in. lines. This same study also found that on the basis of accident reduction, "... 8 in. edgelines appear to be cost effective compared to 4 in. edgelines on two lane rural roads when all three conditions exist:" 1) ADT between 2000 and 5000, 2) 24 ft. wide pavements with unpaved shoulders, and 3) frequent rainfall. The report concludes that further research could verify that "wide edgelines may be more appropriate ... applied at spot locations such as isolated sharp horizontal curves and approaches to narrow bridges

with potentially hazardous unprotected abutments." One study (19) found that wide edgelines are best for short-range steering control commands (compared to roadside delineation).

c. Configuration

General information on lane widths and design of highway elements such as freeway ramp terminals are discussed in AASHTO's "A Policy on Geometric Design of Streets and Highways, 1984." (36) Detailed descriptions of pavement marking configurations are specified by the Manual on Uniform Traffic Control Devices (5). For example, the MUTCD specifies markings to regulate passing, to control turning movements, and markings for intersections. Pavement and lane width requirements can be affected by traffic mix, including bicycles.

The New Jersey Department of Transportation Bicycle Policy (37) states: "The bicycle is a legitimate and viable transportation mode. Therefore, where feasible, roadway projects should be constructed in such a way as to accommodate shared use ..." In accordance with this goal, the New Jersey Department of Transportation Bicycle Planning and Design Guidelines (37) state that: "All state funded projects should provide sufficient width of smoothly paved surface to accommodate the shared use of the roadway by bicycles and motor vehicles. In general, 15' of smoothly paved surface is required in the outside lane (or in the outside lane plus adjacent shoulder) to accommodate shared use." If traffic speeds are more than 45 mph, and heavy

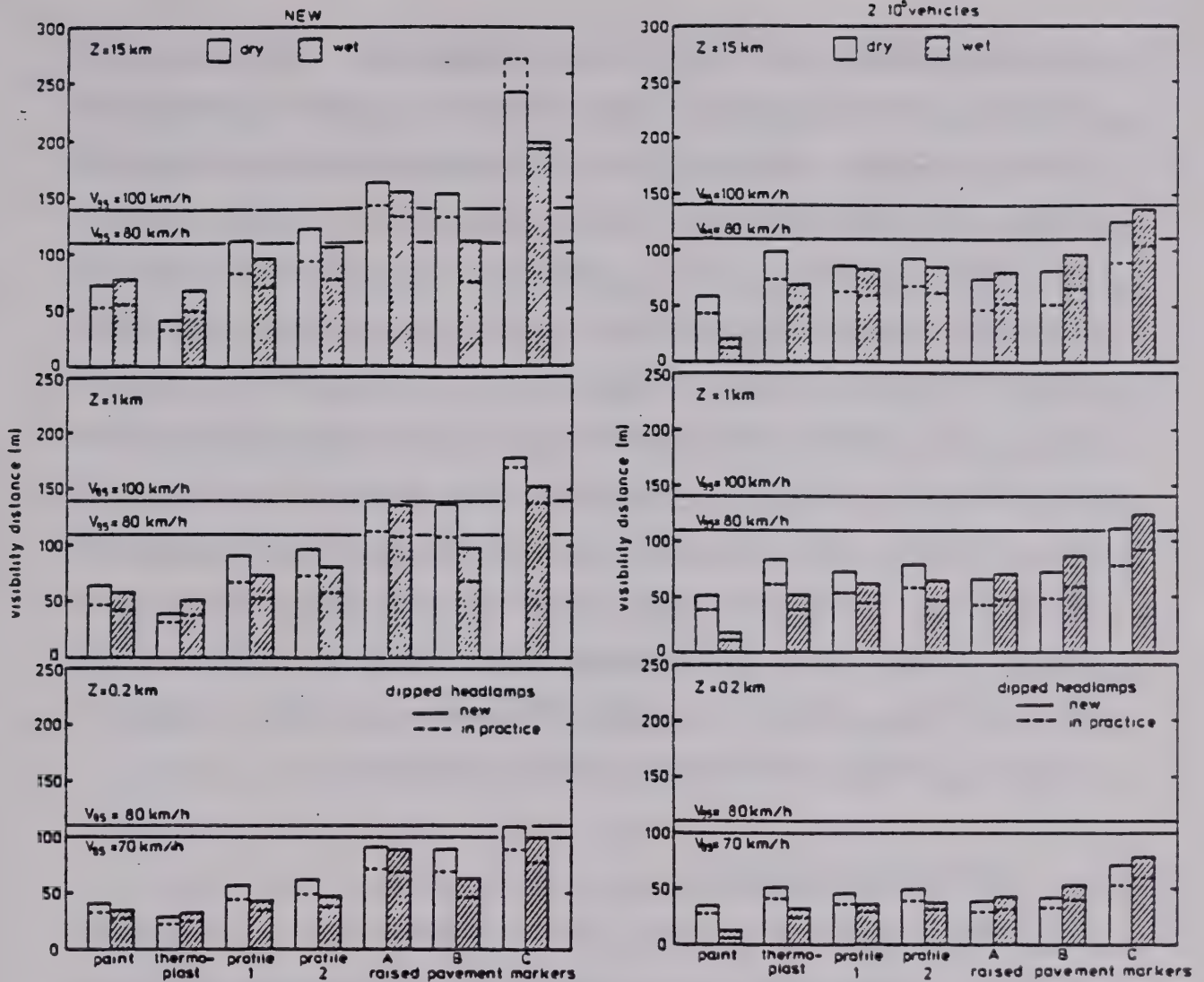
truck traffic is present, shoulders of at least 3 ft. in addition to 15' wide lanes should also be present to accommodate shared use by bicycles and motor vehicles (37). Narrowing inside lanes of multilane roadways could accommodate the needed width in the outside lanes (37).

One study (3), found that the number of stripe "ends" are more important than stripe lengths. Hence, a broken line is more attention getting than a continuous line, however, edgelines should be continuous (21). The MUTCD (5) states that markings do not divert attention from the roadway. Dotted lines are formed with 2 ft. stripes and 4 ft. or longer gaps and may be extended through intersections to guide vehicles through a turn (5). Unfortunately, Capelle (12) found from a survey that many drivers do not understand even simple coded pavement striping messages. The MUTCD (5) also allows short term markings, and requires old, unapplicable markings to be removed.

d. Visibility

Pavement striping effectiveness is a function of delineation contrast. Wet pavement at night can reduce delineation retro-reflectivity which reduces striping effectiveness. Allen (7) found that the probability of leaving the lane is inversely proportional (as an exponential function) to the delineation contrast. Ethan and Woltman of the 3M Co. (29) concluded minimum stripe retro-reflectivity 100 mcd/m²/lx and daytime contrast of the stripe should be at least 3 times the road surface

luminance. They term a stripe luminance of 400 mcd/m²/lx "generally acceptable". Most observers would call this an excellent rating. Bryden et al. (38) formulated retroreflective levels and criteria for striping. The retroreflectivity of beaded paint can vary as beads on the surface wear off and underlying beads are exposed (13). The Traffic Control Devices Handbook (1) says that in wet-night conditions, degraded retroreflectivity of paint, glare, wipers, and slippery pavement make the driving task particularly hazardous and difficult. This hazardous wet-night environment is increased with wider roadways (16). A TRB research problem includes the statement: conventional pavement marking systems lose effectiveness in rainy weather at night (39). This is because the wet pavement resembles a mirror and markings disappear from view (16). Blaauw and Padmos (25) compared the visibility of retroreflective paint with Raised Pavement Markers (RPMs) under wet and dry roadway conditions, and measured visibility distances for the different marking systems. They found the nighttime visibility distance of partially worn retroreflective paint is close to zero on wet pavement after the passing of 2 million vehicles over a two-year period. They developed a pavement marking visibility distance chart which shows the tremendous visibility improvement possible with RPMs, see Figure 1. The acceptance of wet-night visibility as a problem has advanced from the research field into accepted reference works. For instance, the Traffic Control Devices Handbook



Predicted visibility distances immediately after application, for all markings on a dry and wet pavement. Distances are calculated for three atmospheric conditions ($Z = 15$, 1 and 0.2 km) and for new and practice values for the headlamp intensities. The distances are based on the measured retroreflection coefficients. Requirements for minimum visibility distances are given for rural roads with V_{85} velocities of 80 and 100 km/h. The requirements for heavy fog ($Z = 0.2$ km) are lower because of the lower effective speeds on these roads in that condition.

22 months after application of the markings (approximately two million vehicles passed).

Figure 1

Delineation Visibility Distance

(Blaauw G. J. and P. Padmos, 25)

states: "With only painted striping for guidance, wet weather drivers tend to drive erratically within their lane (large lateral variability) and at the same time they show signs of heightened agitation, indicating a greater effort is being exerted." Also, NCHRP 130 (6) mentions that rain greatly reduces the nighttime visibility distance of beaded retroreflective paint. Dale, in the recent NCHRP Synthesis 138, (13) states that the paint and glass bead system "has the serious limitation of losing its visibility at night in wet weather when the drivers need for guidance becomes the greatest. This means that the paint and glass bead marking system needs to be complemented with raised pavement markers or recessed markers or some other type of marker system in order to provide wet-weather night visibility."

e. Wet-Night Visibility

Most pavement stripes are ineffective in wet-night driving conditions; a number of alternative striping formulations have been tested for effectiveness in wet-night conditions, with little success. Regular beaded paint, epoxy paint, polyester markings, and Portland cement combined in mortar form, have been found not to provide adequate wet-night visibility (3,32). Raised and grooved areas added to the lines by impression have been tested to improve drainage of rainwater for the purpose of improving wet-night visibility (40). One study (41) found that similar grooves do not help wet-night visibility, while another, (42) found that the grooves did increase wet-night

visibility, increased paint life, and provided audible warning. "Ribbel-flex" raised thermoplastic line lasted one year, but its delineation benefit was not evaluated (43). The MUTCD (5) states that markings may not be visible when wet and are totally obliterated by snow. Hulbert (16) wrote that street lighting can create glare on wet streets that conceals markings and can cause discomfort itself. Lighting does not make stripes more visible as lighting is subject to the same problem of reflectance from the wet pavement surface as headlights. Most research into special pavement stripes for wet-night conditions has not been successful. RPM's and PMD's have been found to be much more effective in these conditions (1). Research is needed to develop innovative retroreflective pavement marking systems (39). Claims have been made about the potential wet-night delineation abilities of stripes with glass beads larger than are commonly in use. There is at least one study now in progress to evaluate the wet-night delineation capabilities of large-bead striping treatments in New Jersey. The currently proven method of providing wet-night delineation is by the use of RPMs, which break the smooth, wet, road surface to provide the desired retroreflectance. RPM literature will be presented at length in the next part of this paper.

f. Wear and Durability

The best pavement striping materials have the longest life and least cost. Markings may not be durable (5). Dale, in NCHRP Synthesis 138 (13), mentions that curing compounds may decrease paint adherence to fresh PCC surfaces. Dale also claims that two component epoxies are the only markings that perform equally well on portland cement concrete as on bituminous concrete pavements. Bryden (44) made retroreflectance measurements of epoxy traffic stripes ranging from new to six years old and found no correlation of performance to AADT, stripe location, material supplier and contractor, or pavement width. The performance of paint is inconsistent and it may not last over a winter in snow areas (13). Traffic volume directly affects marking life, as does the amount of turning and lane changes (13). The dynamic load of a vehicle going 60 mph is 4 to 5 times the static load of the same vehicle (13). The durability of markings at a given site may not translate to other sites (13). Bryden et. al. (38) formulated retroreflectance levels and criteria for judging pavement markings. Henry et. al. (45) proposed methods to determine the life-cycle cost of pavement markings. Water-borne paint is coming into use and gives off less atmospheric pollutants than traditional paints (13). Epoxy materials are quite safe to handle (13). Dale (13) believes epoxy marking materials can be applied successfully to both portland cement concrete and bituminous concrete surfaces, and that their use in the snowbelt area of the country on high volume roads to provide all year delineation is an important

contribution. Thermoplastic stripes have been shown to be more durable than paint (46), and have been known to last for as long as four years (32); this reduces maintenance operations for repainting (47). Another source mentions that thermoplastic striping lasts 3 to 5 years (13). Thermoplastic markings can be applied over top of existing markings (46). The New York State Policy (48) is to use durable striping materials such as epoxy and thermoplastic on limited access highways and heavily traveled arterials.

g. Discussion

Most of the studies investigating wider-than-normal edgelines found little or no delineation improvement over the base 4" edgelines. These studies vindicate the current use of 4" center and edgelines on New Jersey State Highways. One interesting finding that should be obvious, but that might be overlooked, is that pavement striping does not divert drivers' attention away from the roadway. Also of interest are survey results that show little comprehension by the public of coded delineation information. Research activity in the area of luminance and contrast has not progressed much beyond the theoretical stage. The many investigations into wet night visibility shows a concern by the research community for proper delineation under adverse conditions. The results of several research studies do not support the contention that painted pavement striping is adequate by itself, but rather, that other delineation devices are also needed. The

literature points out again and again that a balanced delineation system is needed which will provide guidance in the many and varied atmospheric and weather conditions drivers encounter in day-to-day driving. Solutions to the problem of roadway visibility in rainy conditions at night will be discussed further in this paper. Interest is apparent in longer lasting pavement striping and most research literature concentrates on thermoplastic and epoxy marking materials.

2. RAISED PAVEMENT MARKERS

a. Visibility

Many research studies report that RPMs are effective for providing roadway delineation in wet-night conditions when conventional striping is ineffective. Several research studies have concluded that when minimum retroreflectivity cannot be maintained on wet roadways RPM's may be appropriate (11), because RPM's are more effective than paint in rainy driving conditions at night (1,12,6) and provide good delineation in wet-night conditions (3,49,13). In addition, RPMs provide good wet-night reflectivity which improves wet-night driver performance (50,1,12). A French study (51) determined that RPMs are the first choice for effective roadway delineation on wet nights. Raised markers are used because they are a durable, day and night, wet and dry marking system whose use is justified in high traffic areas, and because their use along with painted lines provides wet weather night visibility that painted lines

alone do not provide (13). Also, because RPM's protrude above the mirror-like road surface, they provide more positive all-weather delineation; however, they are costly (12,15,16,49). Alexander and Lunenfeld (53) mention that when drivers' expectancy is violated, such as when lane markings diverge from pavement joints, "drivers often have problems, particularly at night, in the rain, when painted lines are nearly invisible. Solutions to this problem involve either making the joints and markings coincide, or making the correct lane markings visible under adverse weather." They also mention that RPM's have been proven effective in providing this needed delineation. RPM's provide near and far delineation (6). Other sources mentioned that RPM's provide wet-night delineation and rumble effect (54), and RPM's can provide good delineation in fog (55). RPM's work in conjunction with pavement striping to provide a complete marking system (13). Retroreflectance is more effective when the eye is close to the headlights--truck drivers receive less luminance from retroreflective treatments than car drivers (21). Some of the stated disadvantages of RPM's include: they are ineffective in snow and can be dazzling and distracting (21, 56).

b. Effect of RPM on Traffic Performance

Raised Pavement Markers improve traffic performance as measured by speed and placement variances, reduce accidents in some situations, and increase driver

comfort. Three references say that RPMs increase curve recognition distance more than any other type of retroreflective treatment when added to pavement markings (57,12,58). Rockwell and Smith in a 1984 FHWA study (58), found that RPMs provide the greatest curve detection distance per dollar (58). Zwahlen (59) claims that four visible RPMs provide a timely detection of a change in direction and a comfortable preview time. Zwahlen also tested RPMs on sharp cloverleaf ramps ($R=240$ ft.) and found that traffic performance did not improve and so he did not recommend RPMs on such ramps. Mallowney (60) found that RPMs reduce erratic maneuvers at exits and curves (more significantly with traffic volumes of less than 500 v/hr/lane), result in smoother speed profiles, and improve wet-night performance almost to the performance found in dry conditions. Others also found that RPM's improve traffic lateral placement patterns, reduce lateral placement variance, and reduce driver stress (3,15). Schwab (15) says that RPMs provide steering guidance in the area near the driver for steering decisions and also far distance cues about road alignment. FHWA research (3) determined that RPM's can reduce erratic maneuvers at lane drops at night. PMD's and RPM's improve traffic performance at exit and merge areas (3). Zwahlen (61) found RPMs are more effective than PMD's and provide a more accurate perception of the driving situation than other forms of supplemental delineation. RPMs can reduce encroachments and speed when

used on narrow bridge approaches (62). Some installations of RPMs show accident reductions and some don't (24). RPMs are preferable to PMDs as they provide different types of guidance--near vs. far (49). RPM's have been used in experimental ways to reduce wrong-way driving (63). The more RPMs are used, the more motorists depend on them; thus, they must be replaced and maintained (16). The most elaborate delineation systems possible are not economically justified (14).

c. Warrants and Spacing

Raised pavement markers should be used on center lines and lane lines and spacing should be a multiple of striping spacing. Supplementing striping with RPM's has the advantage of capitalizing on existing public recognition of striping (56). Two studies (64,49) say that RPM's should be used on center and lane boundaries, but are not normally needed on edgelines. The findings of many other researchers follow: RPMs should not usually be mounted on right edge lines as this may be an obstruction to bicycles, however, RPMs should be used on right edge lines when hazards are present near the roadway edge (37,56). RPMs are effective at isolated hazard areas and provide near, far, and perspective guidance (12). RPMs may be used on curves even if not used on tangents (6). RPMs should be supplemented with PMD's on crest vertical curves (6). Special treatments of one-way retroreflective RPMs only visible on the inside of the

curve have been suggested (49). Amerace Corporation (56) recommends that RPM's not be used to identify Passing zones. RPMs should not be installed on longitudinal joints and should be at least 2 in. from pavement joints (1,47,56). One study said that RPMs should not be installed on asphalt pavement until the pavement is 60 days old (47). NCHRP Synthesis 138 also mentions that allowing new bituminous pavement time to cure increases the service life of RPMs (13).

Zwahlen (61) found that at least four RPMs should always be visible to drivers and recommends a spacing of 120 ft. on tangent Interstates but no use of RPM's on ramps. These recommendations are for RPM's placed on lane lines, on flat, level roadways, with 12 ft. lanes, dark background, young drivers, good headlights, etc. Zwahlen used RPMs that were cut in half to simulate wear. After testing four spacings, Zwahlen determined that 120 ft. is the optimum spacing for RPMs on tangent highways (59). Another study recommended an RPM spacing of 80 ft. (49). Most agree that RPM spacing should be reduced on curves (6,1). Another study found that RPMs should be placed at a 24/48 ft. spacing (47). Blaauw (64) recommends that RPM spacing on center and lane lines be 80 ft. for tangents and 40 ft. on curves up to 9°. Zwahlen (65) later recommended that RPM spacing should be 120 ft. and 25 ft. on ramps. Roberts (66) found a spacing of 80 ft. on tangents, 40 ft. on curves greater than 3 to 4 degree curvature, and 20 ft. on curves greater than 15 degree

curvature, and on gores, allows driver recognition of up to four lanes on a wet night. Amerace Corporation (56) recommends that RPM spacing be reduced to 40 ft. on curves and may be reduced to 20 ft. on problem curves and on gores. Amerace also recommends that spacing be reduced if lane drops or narrowing of the pavement occurs and that spacing may be reduced to 40 ft. starting 160 ft. in advance of intersections. Another study also recommended RPM spacing should be reduced approaching intersections and when they are used to separate exclusive left turn lanes from through lanes (6).

d. Wear and Evaluation

Several reports on threshold visibility requirements and some information on general wear factors are available but there is a lack of objective data on wear and durability of RPM's. McNeese developed evaluation methods to determine if a marker installation is effective (67). Although ASTM D713 (68) specifies test methods for conducting road service tests of traffic paint, raised markers do not have such accepted consensus tests (13). However, raised markers do have technical specifications relating to their design and optical performance (13). Specific intensity and observation angle are needed to measure RPM performance. Reflectivity readings should be compared to a minimum acceptable specific intensity established to determine acceptable performance (65).

Some have said RPM's should have a reflectance of 50 mcd/lx to be visible at 500 ft. during wet-night conditions (69). McNees (70) made photographs of RPM installations and set up panels of 5, 7, or 9 experts to evaluate the photos. The experts were guided to rating an installation as effective, semi-effective (20 to 30 % missing), or ineffective (50 % or more missing). The slides of the actual sites could be compared to standard maintenance slides. Sites rated ineffective should receive immediate maintenance; semi-effective sites should be maintained in the next 6 to 12 months. Roberts (66) found that snowplowable RPM damage is caused by traffic and not entirely by snowplowing. There was some damage from snowplow nose shoes and steel wheels. Shepard found that RPM life is shorter when they are used where turning movements occur (6). Dale (13) mentions that RPM loss is related to truck volumes and the amount of lane changes across markers. Marker loss has also been related to improper mixing of epoxy adhesive, improper surface preparation, and placement of markers on uncured asphalt pavements which are too soft to retain the markers (13). Generalized RPM life expectancies are given in Figure 2, (13). Concerning Figure 2, however, Dale mentions that "Life expectancy of pavement-marking materials as developed at a field test site is a good measure of performance at that site and similar sites. It may or may not translate to other sites." Dale warns that Figure 2 "...may or may not relate to locations of

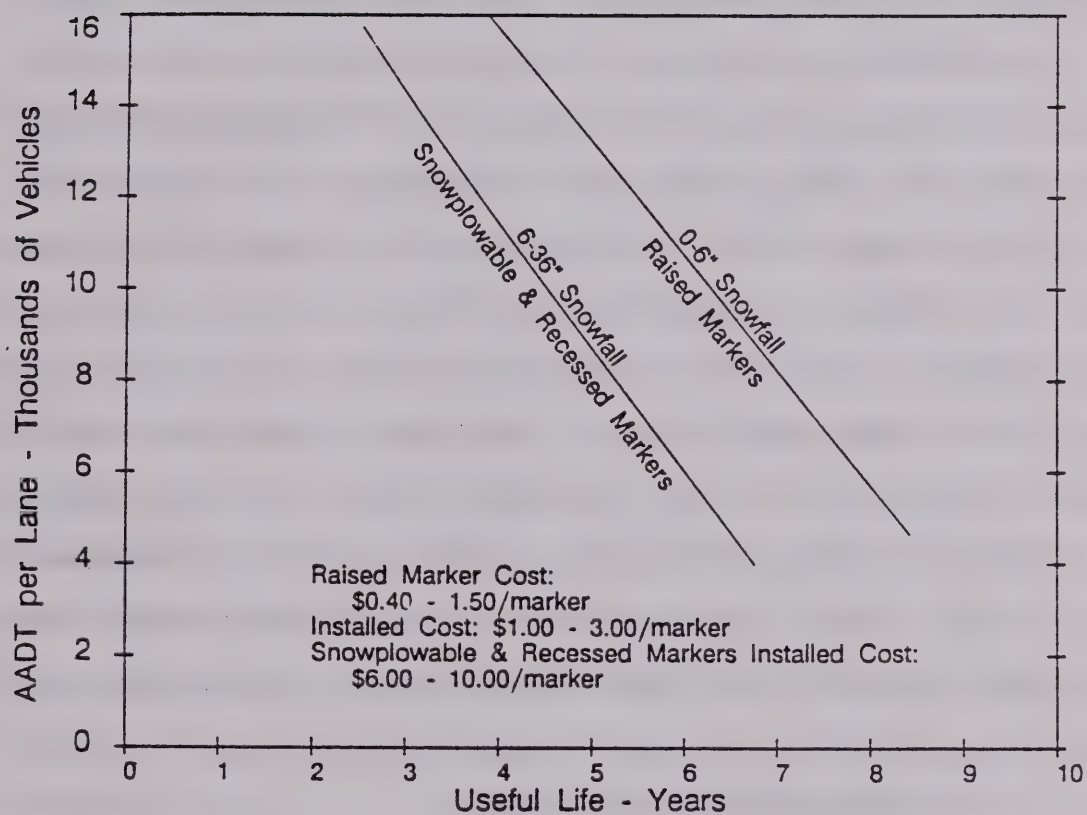


Figure 2

Life expectancy of raised markers, snowplowable, and recessed markers on cured asphaltic concrete and portland cement concrete. (Dale, 13).

interest to the reader." Performance should be measured vs. exposure to predict life in the field (65). Feldhutter determined that glass-faced reflectors are more durable than plastic (54). Two studies that investigated recessed markers found that they do not reflect light well, are not durable, and are in general not very successful (71,72). RPM's were found to be more sensitive to dirt and wear when dry than when wet (25). A visibility distance chart for worn RPM's is available (25), Figure 1. The Province of Ontario (73) and New York State DOT (Bryden, 32) found that the Stimsonite 96 LP was the best of four RPM's tested and that RPM's were good at night in both good and bad weather. Ontario found 25% damage to the 96 LP reflectors after one season on Rt. 7 and 18% damage after one season on Rt. 25. RPM visibility can be reduced by marks, usually from tires (3). One researcher suggests that rather than trying to adapt old RPM designs for snowplow use, use theory to develop new designs from scratch (39).

e. Discussion of RPM Research

Many studies have shown the delineation benefit of RPM's in rainy conditions at night. Some do mention the relatively high cost. Mention was made at a delineation seminar held by Potters Industries Inc., that RPM's are confusing or distracting when used on low speed business streets. This was the only finding of this literature search that said RPM use could have a negative visual

result even though this is a commonly mentioned belief about RPM treatments. Many studies have documented the traffic performance improvements with RPM use. Recommended RPM spacing for tangent situations ranged from 48 ft. to 120 ft. New Jersey's 80 ft. RPM spacing falls within this range. Some scattered research activity was reported in the area of durability and evaluation with one study suggesting that a minimum acceptable threshold should be established for RPM reflective intensity. A small evaluation in Ontario, Canada determined that the Stimsonite 96 LP was the most durable Snowplowable Raised Pavement Marker of four tested. A New York State study also found the 96 LP to be the best of three tested. The authoritative NCHRP 130 report (6) found RPM life is lower when they are used where turning movements occur; this might explain differences in RPM wear rates between jurisdictions because some highway agencies use RPM's as an overall treatment and others use them only at high hazard areas and sharp curves where encroachments and turning actions are higher. Weaving also produces faster RPM wear (66).

B. ROADSIDE AND MEDIAN DELINEATION

1. Post-Mounted Delineators

a. Benefits

Post-mounted delineators (PMD) provide valuable guidance to drivers on curves and are, along with barrier and guiderail delineators, effective when roads are wet or

snow covered. The effectiveness of PMDs depends on the type of retroreflector, its self-cleaning ability, durability, and spacing (74). The air quality can also affect PMD effectiveness. Polluted air can create unwanted coatings on retroreflective material. PMD's provide positive guidance at night, especially if geometry is bad (75). Four studies (57,10,58,76) found PMD's can increase curve detection distance relative to pavement markings alone and can improve driver performance at interchanges. PMD's are visible at larger distances because of their greater height, an advantage when vertical curvature is present (6). Five research studies mentioned the superior delineation provided by PMD's compared to paint during rainy nighttime driving conditions and six mentioned that PMD's provide guidance to drivers during snow when delineation on the pavement is obliterated (75, 15, 2, 1, 5, 56). PMD's may be the only type of delineation visible in inclement weather and so may be needed for snow even if RPM's are present (75,56). The Colorado DOH has specified that flexible post delineators used in their State be the same dark green color as the rigid posts to maximize contrast with snow and for general esthetic appeal (52). Schwab mentions that although PMD's are effective at night and in adverse weather they are not useful for close range steering because of their laterally offset location (15). The Swedish Road Administration found that PMD's do reduce accidents, especially on high speed roads (77). Capelle

claims PMD's are justified by their accident prevention if they last for two years and ADT is 1000 or more (12).

b. Use and Spacing

At least three PMD's should be visible and their use is more frequently recommended on curved rather than tangent roadways. Jennings (78) determined that PMD's are best for delineating moderate curves of 7° or less. Most older standards specify that PMD's should be about 4 ft. high and 6 to 8 ft. from the pavement edge (78). The MUTCD recommends that the height of PMD's should be about four feet and offset should be 2 to 8 ft. (5). More recent work (4) has found that the 4 ft. PMD's are too high (roadway mounted reflectors were found more effective). Also, Zwahlen determined spacing recommendations and that a 1 in. by 18 in. retroreflective strip, 3 ft., 6 in. height, 10 to 14 ft. offset, and 2 black stripes on white are optimum for PMD's (79). The MUTCD allows such elongated reflective units (5). Potters Industries (21) mentions that when 3 to 5 delineators are visible the condition is considered normal. Spacing of PMD's has not been based on this idea but on visibility distance (21). Two reports (3,6) mention that three PMD's should always be visible and that spacing should be 400 ft. on tangents. Another study (12) agrees that a PMD spacing of 400 ft. is adequate, but that four should be visible. The MUTCD requires a spacing of 100 ft. on accel-decel lanes (5). NCHRP 130 (6) recommends the MUTCD

spacing for ramps. NCHRP 130 also recommends that starting 500 ft. in advance of intersections PMD spacing should be reduced to 50 ft. Three studies (6,3) found that PMD spacing should be reduced on curves and in areas of pavement width reduction. The MUTCD gives delineator spacing for curves (5). One study recommends that PMD's should be of a different appearance on ramps and near ramp areas (3). NCHRP 130 recommends that the through lane delineation be strengthened near ramp areas so the through delineation is not overwhelmed by strong ramp delineation (6). For example, PMD use could be introduced in medians on the left of through lanes in interchange areas (6). An isolated finding was that PMD's should be used on the outside of a curve (for example, beyond the opposite lane from a right curve) (49). An article by Merrill Allen, entitled "Visual Hazards on Streets and Highways" (4), claims that PMD's are an obstruction and that they don't provide useful information. He claims that roadside retroreflectors divert the eyes from the road and are deceptive because the posts (at 48 in. high) are higher than most drivers' eyes and present the appearance of floating spots of light with little perspective.

c. Durability

Flexible post delineators have been found to be longer-lasting and safer than the older steel posts. Lovett (80) recommended flexible posts be installed at

high impact areas and where steel posts are knocked-down. Niessner found that flexible posts were twice as expensive to install as rigid posts but are cost-effective because they can withstand repeated impacts that would ruin steel posts (81). Flexible (Carsonite) posts are cost effective but have a mowing problem, for this reason the Mississippi SHD recommended (82) that the flexible posts be used on gores and loops because these areas are somewhat protected from mowing and also elsewhere with closely supervised mowing. Research done by the Colorado DOH (52) determined that flexible posts should be used to replace steel posts whenever the posts are hit more than four times in a year. An Austrian study (54) found glass retroreflectors are more durable than plastic. The MUTCD (5) specifies PMD's should reflect at least 1000 ft. If rail intrudes laterally into the normally clear space between the retroreflectors and the roadway, then the delineators should be in line with the guiderail (5). A 1976 FHWA study (3) mentions that dirt can reduce visibility from 1000 ft. in the clean condition to 100 ft. (3). PMD's were found to be visible 500 ft. when reflectivity (R) was equal to 230 mcd/lx (69). In one case a contract specified R to be 1500. This is far above the minimum level needed (69). A study recommendation was that PMD's should have a reflectance of 230 mcd/lx to be visible at 500 ft. by headlights at night (69).

2. Guiderail Delineation

Guiderail delineation provides valuable information about obstacle location and roadway alignment (41,75). Campi (83) found that delineators can make guiderail more conspicuous at night which should increase detectability and recognition of the guiderail. Also, a reduction in accidents can be a benefit of guiderail delineation. Wet-night visibility of guiderail is a research need and criteria are needed for when guiderail should be delineated. Campi compared different guiderail delineation methods for ease of installation, durability, cost, and appearance. He recommends retroreflective sheeting attached to a flexible post be mounted directly on the guiderail. Although spacing was not specifically studied in this work, Campi recommends guiderail delineator spacing similar to RPM spacing (80 ft. and 40 ft.). Campi also found dirt to be a major problem with retroreflection in urban areas. NCHRP 130 says that guiderail should be delineated if general PMD application isn't being used (6). Conversely, where effective guiderail delineators are in place, separate post mounted delineators are unnecessary.

3. Center Barrier and Median Delineation

Reflectorization can make median areas, including physical barriers, more visible to drivers. From an accident study, Yu (84) found that median visibility is inadequate during hours of darkness. Fog, rain, glare, geometry, and barrier design affect median visibility

needs, especially at night (84). Mallowney (85) determined that permanent concrete barriers are best delineated by acrylic cube-corner retroreflectors mounted on flexible polymeric brackets attached to the top of the barrier. This retroreflective system greatly enhances visibility (85). A benefit of Guiderail delineation is that it functions in adverse weather conditions (1). Washington State DOT (86) claims that barrier delineators should be mounted on the side of the barrier to minimize interference with headlight glare. They are also concerned with dirt accumulation (86). Powers (9) mentions that left curvature and sharp curves are more difficult to delineate. Powers recommends 80 ft. spacing for top mounted center barrier delineators except on curves of 2° or more where 40 ft. spacing is needed. However, even with variable spacing, some sites will be less well delineated than others (9). Three delineators should always be visible (9).

4. Chevrons

Chevron alignment signs provide a similar type of guidance as do post-mounted delineators and provide a directional message and greater height for good guidance on sharp combination horizontal and vertical curves. The MUTCD (5) recommends that the signs be visible for at least 500 ft. This would be met for all vertical curves designed for stopping sight distance according to AASHTO's "A Policy on Geometric Design of Highways and Streets,

1984," (36) whenever the design speed of the roadway is 40 mph or greater. In these cases the minimum 5 ft. mounting height from the pavement edge to the bottom of the sign provides the desired visibility distance. The visibility distance may be adequate on vertical curves designed for speeds lower than 40 mph when the curve length is longer than the minimum. The MUTCD suggests trial runs by day and at night to determine final positioning. Zador et. al. (57) found that chevrons increase curve detection distance. Jennings and Demetsky (78) recommend chevrons on curves of 7° or more as they reduced centerline encroachment, placement variances, and speed. Allen (19) states that chevron alignment signs provide long-range curve recognition.

5. Discussion of Roadside and Median Delineation

Roadside and median retroreflectors provide valuable visibility cues for drivers. One of the benefits of this type of delineation is the ability to make the road edge more visible when hazards are near the road. Certainly apparent is the value of PMDs as an effective form of delineation in snowy weather conditions because pavement markings and RPM's are completely useless when roads are snow covered. Where ramps and curved roadways are present PMD's provide the only guidance until traffic, plowing, or rain can clean roadways completely. If guiderails or concrete barriers are present on ramps they should be retroreflectorized for rainy nighttime driving to

substitute for post delineators. Chevron alignment signs are particularly valuable on combination curves where a crest vertical curve is combined with a horizontal curve. Under these conditions, the height of the chevron signs and their directional message provides information unavailable from any other source.

C. Combinations of Delineation

The best delineation system would consist of center, lane, and edgelines, raised pavement markers, and roadside and median retroreflection of the type appropriate for the existing furniture. A few research studies evaluate combinations of delineation treatments directly, a combination of pavement striping and roadside retroreflectorization would provide close-range steering control, long-range guidance, and visibility for bad weather.

A major study done by the FHWA in 1977 (49) evaluated 18 different combinations of delineation treatments including different widths of striping, different gap and stripe ratios, and various RPM and PMD treatments. Although stripes narrower than 4 in. and with a gap ratio of less than 3:1 were judged adequate in some limited situations, the 4 in. lines with a 10/30 ft. ratio were recommended for general installation. RPM's added to lane lines were found to provide a visibility benefit in wet-night conditions. The report recommends an 80 ft. basic RPM spacing but RPM's are not recommended for right edgelines as they only improve performance slightly.

Another report synthesized several FHWA studies in 1978 (12). This study claimed that PMD's were economically justified whenever AADT was 1000 or more. RPM use in addition to the recommended 4 in. center and edge lines reduced the vehicle lateral placement variance in the lane by 50% (12).

NCHRP 130 (6) found that RPM's and PMD's used together improved driver's lateral placement variance compared to a center line and PMD combination. Any delineation is better than none, and RPM's on the center line reduced placement variability (6). Rockwell and Smith of the Ohio State University (10) found that RPM's combined with striping provided the largest increase in curve recognition distance of any single supplemental device. They found that with more delineation, driver behavior became less variable. Rockwell and Smith tested a number of combinations of delineators for rural highways. They found striping, RPM's, and PMDs used together provided the greatest curve recognition distance and that RPMs added to striping provided the greatest visibility distance per dollar spent. NCHRP 130 mentions that RPM's do improve performance compared to pavement striping and PMD's (6). Amerace Corporation (56) recommends combining RPM's with painted striping as a way of taking advantage of existing public recognition of stripes. They also recommend roadside delineation. The more delineation present on a road, the better is the drivers' visibility. Raised pavement markers offer

advantages in visibility and traffic performance and so are valuable to use.

RPM use does not eliminate the need for roadside retroreflectorization, however, because of the different characteristics of these treatments. For example, NCHRP 130 (6) brings up the need for PMDs to supplement RPMs on vertical crest curves where the additional height gives a greater visibility distance. The Executive Summary of an FHWA Delineation Conference (2) mentions that delineation must provide adequate information when the driver's expectations are violated, such as at a left-hand exit, which is a non-standard design. This summary recommends stripes, RPM's, flexible post delineators, and barrier delineation be used in combination. Either post, guiderail, or concrete barrier retroreflective treatments are appropriate for median areas. NCHRP 130 (6) says that guiderail should be delineated if PMD's are not in place adjacent to the guiderail. The same study states: "through" or "mainline flow" delineation should be strengthened in areas of ramps so that the through delineation is not overwhelmed (6). For example, edgelines could be continued past merge areas, or this could be done with median treatments (6). RPM's should be used on center and lane lines and on edgelines where needed to emphasize obstructions and constrictions in roadside geometry. The use of all these devices is not necessarily over-delineation, or wasting of delineation, but rather such issues as stripe width and skip ratios,

RPM spacing, and PMD and roadside retroreflector spacing impact on the economy of a roadway safety system. NCHRP 130 (6) also notes that elaborate or "over-delineation" has been proven not to encourage or increase illegal speeding. Traffic performance improves with added delineation; the improvement becomes less and less as total delineation cost increases (49). In other words, some systems tested provided a great benefit but at a high cost (12).

WORK ZONE DELINEATION

Work Zone delineation includes both longer-term construction projects and shorter maintenance-type road closures. Both short-term maintenance closures and construction zones may be referred to as "Work Zones". The following sections discuss general concepts concerning work zone traffic control, channelizing devices, roadway delineation and roadside delineation. Research literature was identified in these categories, which describe work zone traffic control in the Manual on Uniform Traffic Control Devices.

A. Work Zone Traffic Control

Too few or poorly organized warning devices are often times a partial cause of accidents in work zones (87). Paths of travel should show up in day, dry, wet, twilight, and night conditions (5). Work zone delineation should be clear and should overwhelm old pavement markings and joints while being designed to be as comparable as

possible to regular traffic control (88,89). Work zone delineation should be compatible with traffic speeds and should be designed to maintain speed (89). Delineation not consistent with geometry may increase accidents (90). Delineation should guide motorists in a clear, positive manner (5). Traffic movement should be inhibited as little as possible (5). Richards (91) found that reduced lane widths can reduce speed in construction zones, although lanes of 9 or 10 ft. wide also increase erratic maneuvers. Combinations of traffic control elements provide the needed traffic control in work zones (5). Traffic control devices require frequent inspection, including drive through checks of pavement markings both day and night (5). Traffic control devices require regular maintenance and conflicting markings should be removed (89,5). Someone should be assigned on a day-to-day basis to be responsible for the traffic control plan (92). Traffic control design should assume that drivers will reduce speed only if they feel it is necessary (92). Research (88) found that delineation with a lower mounting height provides better lateral guidance to drivers. Delineation on the road provides the best lateral perception guidance (93). Shepard recommends that where night work is being done that barrels or Type I or Type II barricades with steady burn lights be used in conjunction with signs, arrowboards, impact attenuators, flagging, and a minimum of 1000 ft. sight distance to the lane closure (94).

B. Channelizers

Channelizers force traffic into the desired travel path at the beginning of a lane closure or roadway diversion. Cones, tubes, barrels, and vertical panels are examples of channelizers. Cones are the smallest, least visible type of channelizer, but they are the cheapest and easiest to place on the road. Cones are easy to place but need weights so wind won't cause overturning (5). Cones may blow over easily (90). Cones need 200 square inches of retroreflective area at night (90). The MUTCD requires cones to be reflectorized with a 6-inch white reflective band. The larger, 28-inch cones require a supplemental 4-inch white reflective band located 2 inches below the 6-inch band. The 28 inch high cones are the minimum height recommended by the MUTCD for freeways and at night (5). Richards (91) reports that cones are quick and easy to install but that they were frequently hit by trucks and RV's. Plastic barrels are reusable and cause less damage in accidents compared to steel barrels (95). Barrels need to be properly ballasted (95). A value engineering study found vertical panels or drums to provide the most delineation per dollar spent (96). Plastic barrels with vertical tall panels provide superior visibility (97). An FHWA report (98) found that channelizers (barricades, drums, cones, and panels) should be visible for 900 ft. for use at 55 mph in clear weather with low-beam headlights. Davis (99) discovered that tall

Panel Channelizers required less space, were more visible over leading vehicles, reduced lane encroachments and didn't change speed or speed variance while being cheaper than Type III barricades used as channelizers. In another study by Davis (100), traffic performance improved when vertical tall panels were used on top of barrels. Inadequate or inconsistent taper areas may cause accidents (90). Arrowboards should be used only for lane closures (90), not for shoulder work or closures.

C. Barricades as Channelizers

Type III Barricades serve as channelizing devices, although they were not originally designed for this purpose. The MUTCD (5) states that barricades are for closing, delineating, or restricting all or a portion of the right-of-way. The MUTCD goes on to say that Types I and II barricades are for areas where traffic is maintained and may be used as channelizers; type I for local streets, and type II for highways. According to the MUTCD (5), Type III barricades are for road closures and extend completely across a roadway (local traffic only is allowed to pass). Wing barricades may be mounted on shoulders and brought closer to the pavement in advance of a zone (even where no part of the roadway is actually closed) (5). Signs may be mounted on wing barricades (5). Direction of stripes on barricades were found to be ineffective for telling drivers which way to go, but chevron signs used as a supplemental device give

good directional information (90). The size of channelizers relates to their effectiveness (90). Donaldson (97) indicates that Type III barricades have a significant impairment of decision sight distance for drivers. Barrels supplemented with tall panels are highly visible over long distances and are more easily detectable than barricades (90). Their reflective area is smaller than the Type III barricades which are used as channelizers (90). The barrel-tall panel combination is being used in certain situations by the New Jersey DOT.

D. Temporary Markings

Rather than using paint for temporary pavement markings, removable tape can be more convenient because of its relative ease of removal. Davis mentions that tape is easy to install and remove and has good visibility (99). Temporary markings should be removed when travel alignments change (92). Confusion due to pavement joints and different color pavements impacts on delineation use and design in construction zones (92). Tape is easily removable after a construction project (97). Davis (100) reports that removable traffic tape was problem free and as visible as paint. Dudek (101) evaluated different abbreviated pavement marking patterns in a proving ground study for interim use in partly completed work zones and found 8 ft. stripes with 32 ft. gaps and RPMs produced the least erratic maneuvers and were preferred by drivers. Another more recent study

found 2 ft. stripes to be adequate on two lane unlighted rural highways (102). The MUTCD (5) currently allows four foot long stripes at the regular marking cycle length. This applies to pavement markings that are to be in place for up to two weeks.

E. Temporary Raised Pavement Markers

Raised pavement markers provide the same visibility advantages in construction zones as they do in permanent installations, namely, improved nighttime and wet-night visibility. The poor geometric conditions sometimes found in work zones increases the need for supplementing pavement striping with additional delineation. Davis (99) made measurements proving that temporary RPMs used as a paint supplement reduced lane weaving and encroachments day and night. Temporary RPMs provide superior delineation in darkness and inclement weather (97). Davis (100) found temporary RPMs as a paint supplement reduced lane changes and encroachments at night. RPM's alone (without paint or tape) were slightly less visible in daylight but better at night and improved traffic performance (100). Niessner (103) mentioned that temporary RPMs provide good delineation in both day and night as well as bad weather. NCHRP Synthesis 138 (13) recommends the use of tape along with the RPMs.

Important features of temporary RPMs are: streamlined shape, type of retroreflector, and balance between a day visible casing and reflector area (104). More durable

markers and better adhesives need to be found (103). Adhesives other than butyl pads need research (104). A 1976 FHWA report (47) claims that the bottom of temporary RPMs should be textured rather than flat. One finding is that RPM's are easy to remove (100).

Niessner (103) recommends spacing of 20 to 40 ft. with paint and 6 to 10 ft. without paint. Ohio (105) found that spacings of 5 to 10 ft. were suitable for replacing stripes with temporary RPM's. Also, 10 to 20 ft. spacings were appropriate for supplementing pavement markings. Kentucky (106) found that a 5 ft. spacing is necessary to replace a stripe with temporary RPMs, while 10 ft. spacing is adequate for supplementing tape. The MUTCD (5) requires a 5 ft. spacing when RPMs replace a solid line. The MUTCD (5) specifies that broken line segments be substituted by groups of four or five markers spaced at $N/12$ along the stripe. The MUTCD also requires all RPMs used in work zones to be retroreflective as well as being visible during the daytime.

F. Temporary Barrier

Concrete median barriers provide a protective separation of opposing traffic but can be a hazard to errant vehicles; retroreflection increases night visibility of barriers to minimize accidental impacts. Of course, median retroreflection also provides advantages similar to post mounted delineators such as long-range roadway alignment information and adverse weather delineation.

The FHWA (92) maintains that although temporary barriers are expensive they provide safety in high volume, high-speed situations. Likewise, the MUTCD (5) states that temporary barriers should be used where needed for protection; not just for channelization and that the barriers require delineation. Ohio DOT (107) found that larger devices on top and retroreflectors on the side of barriers provided good delineation and that the spacing of devices should be no more than 25 ft. Research by Davis in New Jersey (100) found that 5 by 10 in. high intensity sheeting retroreflectors did not change traffic performance compared to steady-burn lights. Davis concluded that the best method of delineation is with 6 by 12 in. retroreflective sheeting panels spaced at 100 ft. on tangents and 50 ft. on curves (99).

G. Discussion of Work Zone Delineation

In the substandard geometric conditions that exist in many construction zones, extra care is needed in the design and application of traffic control systems. Combinations of items such as channelizers, signs, and pavement markings can make the intended travel paths visible. Research done on channelizers found barrels and tall panels to perform well and that cones are appropriate for short-term, daytime closures. The evidence for the use of Type III barricades as channelizers is not strongly in their favor. The main point against the use of such devices is their extreme width that may block the driver's

view. The barrels and tall panel channelizers provide a more simple appearance which contributes to a good view of the road ahead.

Removable pavement marking tape is convenient to use for temporary lane and edge lines and few problems with its use are reported in the literature. Temporary RPMs are a helpful supplement to tape and several research studies found that temporary RPMs can also serve alone as the primary delineation method. Temporary RPMs must be retroreflective if they are to be used as a stand-alone marking system. The several studies of temporary concrete barrier delineation found that where the barriers are needed, they should be retroreflectorized. Top-mounted retroreflectors were recommended and the retroreflective sheeting panels mentioned were found to provide good nighttime visibility.

ACKNOWLEDGMENTS

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LIST OF REFERENCES

1. Traffic Control Devices Handbook Part III - Markings.
Federal Highway Administration, 1983.
2. Delineation Conference Executive Summary, Report No.
FHWA-TS-77-217, Federal Highway Administration, November
1977.
3. Bali, S.G., McGee, H, and Taylor J., State-of-the-Art on
Roadway Delineation Systems, Report No. FHWA-76-53-13,
Federal Highway Administration, 1976.
4. Allen, M., Vision and Highway Safety, 1969, Chapter 9:
Visual Hazards on Streets and Highways, p. 141-176.
5. Manual on Uniform Traffic Control Devices for Streets and
Highways, Federal Highway Administration, March 1988.
6. Taylor, J.I., McGee, H.W., Sequin, E.L., and
Hostetter, R.S., NCHRP Report No. 130: Roadway
Delineation Systems, Highway Research Board, 1972.
7. Allen, R.W. and Hanlon, J.F., Effects of Roadway
Delineation and Visibility Conditions on Driver Steering
Performance, Transportation Research Record No. 739,
Transportation Research Board, 1979.

8. Allen R.W. and O'Hanlon, J. F., Driver Steering Performance Effects of Roadway Delineation and Visibility Conditions, Paper No. 229, Systems Technology Inc.
9. Powers, J.C., Center Barrier Delineator Spacing, Report No. FHWA-NJ-88-013-7714, New Jersey Department of Transportation, April 1988.
10. Nemeth, Z.A. et al., Effect of Delineation System on Curve Detection Distances Under Simulated Rural Nighttime Driving Conditions, Part 2, Ohio Department of Transportation, Report No. EES-627.
11. Freedman, M., Noticeability Requirements for Delineation on Non-Illuminated Highways, Report No. FHWA-RD-88-028, Federal Highway Administration, July 1988.
12. Capelle, D.G., An Overview of Roadway Delineation Research, Report No. FHWA-RD-78-111, Federal Highway Administration, June 1978.
13. Dale, J.M., Pavement Markings: Materials and Applications for Extended Service Life, NCHRP Synthesis No. 138, Transportation Research Board, June 1988.
14. Walton, N., Fixed Illumination as a Function of Driver Needs, TRB Special Report No. 156, Driver Visual Needs in Night Driving, Transportation Research Board.

15. Schwab R. and Capelle, D., Is Delineation Needed?, Public Roads, December 1979, Vol. 3, No. 3.
16. Hulbert, S., Reflectorized Information Needs: Wet Pavement, Transportation Research Circular No. 306, Transportation Research Board, June 1986.
17. Roadway Design Manual, New Jersey Department of Transportation, April 1988.
18. Godthelp, H. and Moreal, J., Studies on Vehicle Guidance and Control, Presented at Transportation Research Board Annual Meeting, 1985.
19. Allen, R.W., Reflectorization of Curves, Presented at Session 105, Presented at Transportation Research Board Annual Meeting, 1984.
20. Rinalducci, E.J. and Beare, A.N., Visibility Losses Caused by Transient Adaptation at Low Luminance Levels, TRB Special Report No. 156, Transportation Research Board, 1986.
21. Vision and Roadway Delineation, Potters Industries Inc. Seminar, January 1984.

22. Reflectorized Devices for Driver Information, Transportation Research Circular No. 306, Transportation Research Board, June 1986, Introduction, p. 1-2.
23. Vanstrum, R.C. and Landen, J.C., The Dark Side of Driving, Transportation Quarterly, Vol. 38, No. 4, October 1984.
24. Nemeth, Z., Pavement Markers Prevent Crashes-If They Are Rationally Used, Traffic Safety, May/June 1984.
25. Blaauw, G.J. and Padmos, P., Nighttime Visibility of Various Types of Road Markings, SAE Technical Paper No. 820412, Presented at the International Congress and Exposition, February 1982, Society of Automotive Engineers.
26. Brodsky H. and Harkkert, A.S., Risk Assessment of Rain on Road Accidents, Presented at Transportation Research Board Annual Meeting January 1986.
27. Nick, J.B., Reflective Characteristics of Roadway Pavements During Wet Weather, Transportation Research Circular No. 297, Transportation Research Board, December 1985.
28. De jaiffe, R., Measuring Wet Night Delineation Reflectivity, Transportation Research Record No. 1149, Transportation Research Board, 1987.

29. Ethan, J. and Woltman, H., Minimum Retro-reflectance for Nighttime Visibility of Pavement Markings, TRB Pre-print No. 65-53.01, Transportation Research Board, 1986.
30. Glennon, J.C., Accident Effects of Centerline Markings on Low-Volume Rural Roads, Transportation Research Record No. 1027, Transportation Research Board, 1985.
31. Cottrell, B.H., Jr., Effects of Wide Edgelines on Lateral Placement and Speed on Two Lane Rural Roads, TRB Pre-print No. 65-500.05, Transportation Research Board, 1986.
32. Bryden, J.E. and Lorini, R.A., Experimental Pavement Delineation Treatments, Report No. FHWA/NY-RR-81/87, Engineering Research and Development Bureau, New York State Department of Transportation, June 1981.
33. Hall, J.W., Evaluation of Wide Edgelines, Presented at Session 5, Transportation Research Board Annual Meeting, 1987.
34. Szalaj, W.M., Effect of Width on Edge Line Life, Report No. FHWA-NJ-89-003-7728, New Jersey Department of Transportation.
35. Hughes, W.E., McGee, H.W., Hussain, S., and Kegall, J., Field Evaluation of Edgeline Widths, Federal Highway Administration, Report No. FHWA-RD-89-111, December 1989.

36. A Policy on Geometric Design of Highways and Streets, 1984, American Association of State Highway and Transportation Officials, Washington, DC.
37. Bicycle Compatible Roadways Planning and Design Guidelines, New Jersey Department of Transportation, December 1982.
38. Bryden, J.E., Lorini, R. A., and Kelly, P.D., Reflectivity and Durability of Epoxy Pavement Markings, Transportation Research Record No. 1086, Transportation Research Board, 1986.
39. Highway Visibility Research Needs, Transportation Research Circular No. 222, Transportation Research Board, October 1980.
40. Hofmann, F., The Improvement Under Wet Conditions of the Nighttime Visibility of Carriageway Markings, German Research Report, TRR Laboratory, IRRD 310504.
41. Highway Safety Review, Safety Review Task Force Report to FHWA Administrator, Report No. US-78-51-2, Federal Highway Administration.
42. Cahoon, R.L. and Cruz, B.E., Use of a Rumble Stripe to Reduce Maintenance and Increase Driving Safety, Materials and Tests Division, Utah State Department of Highways, 1970.

43. Dejaiffe, R., Wet Night Thermoplastic Markings, Potters Industries Inc., Presented at Transportation Research Board Annual Meeting 1987.
44. Bryden, J.E., Lorini, R.A., and Kelly, P.D., Reflectivity and Durability of Epoxy Pavement Markings, Transportation Research Record No. 1086, Transportation Research Board, 1986.
45. Henry, J.J. et al., Determination of Life Cycle Costs of Pavement Marking Materials, Pennsylvania Transportation Institute, Pennsylvania State University, 1987.
46. Frascoia, R.I. et. al., Evaluation of Thermoplastic Pavement Markings on Vermont Routes 15 and 100, Vermont Agency of Transportation, March 1987.
47. Optimization of Traffic Lane Delineation Executive Summary, Report No. FHWA-TS-77-200-1, Federal Highway Administration, 1976.
48. Pavement Marking Policy, New York State Department of Transportation, June 1987.
49. Stimpson, W.A., Field Evaluation of Selected Delineation Treatments Executive Summary, Report No. FHWA-RD-77-119, Federal Highway Administration, October 1977.

50. Shepard, F.D., Summary of Research on Snowplowable Raised Pavement Markers and Recommendations for Placing Markers, Virginia Highway and Transportation Research Council, 1981.
51. Schreuder, D.A., The Visibility of Carriageway Markings on Wet Roads, Report No. IRRD 108568, Central Laboratories of Bridges and Highways, France.
52. Swanson, H.N., and Woodham, D.B., Flexible Roadside Delineator Post Evaluation, Report No. CODOH-DTD-R-88-17, Colorado Department of Highways, August 1988.
53. Alexander, G.J., and Lunenfeld, H., Driver Expectancy in Highway Design and Traffic Operations, Report No. FHWA-TO-86-1, Federal Highway Administration, April 1986.
54. Feldhutter, R., Glass Reflectors for Safer Roads at Nighttime, Austria, January 1980.
55. Shepard, F.D., Evaluation of Raised Pavement Markers for Roadway Delineation During Fog, Report No. VHTRC 77-R21, Virginia Highway and Transportation Research Council, October 1976.
56. Recommendations for the Use of Raised Reflective Pavement Markers, Signal Products Division, Amerace Corporation.

57. Zador, P. et al., Effects of Chevrons, Post-Mounted Delineators, and Raised Pavement Markers on Driver Behavior at Roadway Curves, Presented at Transportation Research Board Annual Meeting, 1987.
58. Rockwell, T.H. and Smith G.L., Recommended Delineation Treatments at Selected Situations on Rural State Highways, Report No. FHWA-OH-85-002, Federal Highway Administration, 1985.
59. Zwahlen, H.T., Driver Lateral Control Performance as a Function of Delineation, Transportation Research Record No. 1149, Transportation Research Board, 1987.
60. Mullowney, W.L., Effect of SRPM on Traffic Performance, Report No. FHWA/NJ-83-001-7769, New Jersey Department of Transportation.
61. Zwahlen, H.T., Optimal Placement of Reflective Markers, Report No. 14354(0), Vol.1, Ohio Department of Transportation, August 1985.
62. Richards, S.H. and Dudek, C.L., Selections of Work Zone Channelizing Devices Using the Value Engineering Approach, Transportation Research Record No. 1035, Transportation Research Board, 1985.

63. Shepard F.D., Evaluation of Raised Pavement Markers for Reducing Incidences of Wrong Way Driving, Transportation Research Board, 1976.
64. Blaauw, G.J., Vehicle Guidance by Delineation Systems at Night, Paper Given at the Fourth European Conference on Human Decision Making and Manual Control, Soesterberg, Netherlands, May 1984.
65. Zwahlen, H.T., Snowplowable Raised Pavement Markers, Transportation Research Circular No. 306, Transportation Research Board, June 1986.
66. Jagannath, M.V. and Roberts, A.W., Evaluation of SRPM's in New Jersey, Report No. FHWA-NJ-RD-77-004-7708, New Jersey Department of Transportation, August 1976.
67. McNees, R., Establishing a Minimum Functional Reflectance for Raised Pavement Markers, Paper presented at the Visibility Symposium for Highway Guidance and Hazard Detection, June 1986.
68. Conducting Road Service Tests on Traffic Paint, American Society for Testing and Materials, D713, Annual book of ASTM Standards, Volume 6.01.

69. Michaut, M., Colomb, Mmse., and Bry, M., Visibility Thresholds in Night Driving Conditions, Transportation Research Circular No. 297, Transportation Research Board, December 1985.
70. McNees, R.W., Establishing a Minimum Functional Reflectance for Raised Pavement Markers, Transportation Research Record No. 1149, Transportation Research Board, 1987.
71. Low Profile Markers for Wet Night Visibility, Report No. FHWA-TS-79-205, Federal Highway Administration, Region 8, 1979.
72. Delineation Conference Narrative Summary, Part I-IV, Report No. FHWA-TS-78-219, Federal Highway Administration, 1978.
73. Loughheed, J.F., Performance Evaluation of Snowplowable Raised Pavement Markers, Ontario Ministry of Transportation and Communications, April 1986.
74. Yu, J. and Arnn, A., Roadside Delineation Concepts: A National Study, Highway Research Record No. 440, Highway Research Board, 1973.
75. Weed, D., Revised Decision Criteria for Before/After Analysis, Presented at Transportation Research Board Annual Meeting, January 1986.

76. Darrell, J.E.P. and Dunnette, M.D., Driver Performance Related to Interchange Marking and Nighttime Visibility Conditions, Highway Research Bulletin No. 255, Highway Research Board, 1960.
77. Traffic Safety Effect of Guide Posts, TRR Laboratory Report No. IRRD 252937, National Swedish Road Administration.
78. B.E. Jennings and Demetsky, Evaluation of Curve Delineation Signs, Transportation Research Record No. 1010, Transportation Research Board, 1985.
79. Zwahlen, H.T., Optimization of Post Delineator Height and Spacing, Report No. FHWA-OH-86-015-016, Ohio Department of Transportation, 1986.
80. Lovett, F., Flexible Delineator Posts, New Jersey Department of Transportation, December, 1985.
81. Niessner, C.W., Post Mounted Delineators, Report No. FHWA-TS-83-208, Federal Highway Administration, July 1983.
82. Kidd, S.Q., An Evaluation of Carsonite Curve Flex Delineator Posts, State Study No. 67-8, Mississippi State Highway Department, October, 1987.
83. Campi, J., Guiderail Delineation, New Jersey Department of Transportation, 1989.

84. YU, J.S., Median Visibility Improvements: Needs, Methods, and Trends, Highway Research Record No. 366, Highway Research Board, 1971.
85. Mullowney, W.L., Center Barrier Visibility Study, Report No. FHWA-NJ-80-002-7710, New Jersey Department of Transportation January 1978.
86. Ugwoaba, G.V., Evaluation of Delineation Systems for Temporary Traffic Barriers in Work Zones, Washington State Department of Transportation, May 1987.
87. Visibility in Construction and Maintenance Work Zones, Transportation Research Circular No. 232, Transportation Research Board, October 1981.
88. Godthelp, J. and Riemersma, J. B., Vechile Guidance in Road Work Zones, Ergonomics, Vol. 25, No. 10, 1982.
89. Work Zone Traffic Control, American Traffic Safety Services Association, Fredericksburg, Virginia.
90. Pain, Hanscom, and McGee, Work Site Traffic Controls in the U.S.: Existing and New Technologies, Traffic Engineering and Control, October 1983.

91. Richards, S.H. and Dudek, C.L., Implementation of Work Zone Speed Control Measures, Transportation Research Record No. 1086, Transportation Research Board, 1986.
92. Russel, P.O., Overview of Safety Issues for Work Zones, From Proceedings of the Symposium on Work Zone Traffic Control, February 1985, Report No. DOT-I-86-05, Federal Highway Administration.
93. Godthelp H. and Rimersma, J. B., Perception of Delineation Devices in Road Work Zones Driving Nighttime, SAE Technical Paper No. 820413, Presented at the International Congress and Exposition, February 1982, Society of Automotive Engineers.
94. Shepard, F.D. and Cottrell, Jr., B.H., Benefits and Safety Impact of Night Work-Zone Activities, Transportation Research Record No. 1086, 1986.
95. Riedel, C.W., Safer Work Zones Channelization with Plastic Drums, ITE Journal, Vol. 56, No. 9, September 1986.
96. Richards, S.H. and Dudek, C.L., Selection of Work Zone Channelizing Devices Using the Value Engineering Approach, Transportation Research Record No. 1035, Transportation Research Board, 1985.

97. Donaldson, G., Synthesis of Group Meeting: Traffic Control for Work Zones on Freeways, Report NO. DOT-1-86-05, Center for Auto Safety, February 1985.
98. McGee, H.W., and Knapp, B.G., Visibility Requirements of Work Zone Traffic Control Devices, Report No. FHWA-RD-78-143, Federal Highway Administration, July 1978.
99. Davis, T., Construction Zone Delineation, (Abridgement) Transportation Research Record 811, Transportation Research Board, 1981.
100. Davis, T., Construction Zone Safety and Delineation, Report No. FHWA-NJ-83-005-7768, New Jersey Department of Transportation, February 1983.
101. Dudek, C.L., Huchingson, R.D., and Woods, D.L., Evaluation of Temporary Pavement Marking Patterns in Work Zones: Proving Ground Studies, Transportation Research Record No. 1086, Transportation Research Board, 1986.
102. Dudek, C.L., Huchingson, R.D., Creasey F.T., and Pendleton, O., Field Studies of Temporary Pavement Markings at Overlay Project Work Zones on Two-Lane, Two-Way Rural Highways, Transportation Research Record No. 1160,

103. Niessner, C.W., Construction Zone Delineation (Raised Pavement Markers), Report No. FHWA-TS-78-222, Federal Transportation Research Board, 1988 Highway Administration, June 1978.
104. Davis, T., Evaluation of Temporary Day-Night Visible RPM Adequacy, Transportation Research Record No. 1086, Transportation Research Board, 1986.
105. Khan, M., Evaluation of TRPM's in Work Zones, Ohio Department of Transportation, February 1987.
106. Agent, K.R., and Pigman, I.G., Evaluation of Construction Zone Pavement Marking Materials, Kentucky Transportation Research Program, September 1985.
107. Khan, M., Evaluation of Delineation Systems for Temporary Traffic Barriers in Work Zones, Ohio Department of Transportation, December 1985.

APPENDIX C
FIELD REPORT ON HIGHWAY DELINEATION

TO List

MEMORANDUM

FROM R. L. HollingerSUBJECT Delineation Guidelines DATE 2/1/89 TELEPHONE NO. 2-4718
Survey

Please read the attached report on roadway delineation to prepare for a questionnaire which will be sent to you next week. The report contains information which will be helpful in answering the questionnaire.

The questionnaire which you will receive is one method the Bureau of Transportation Systems Research is using to collect information on delineation from Department professionals as part of a research project.

Richard L. Hollinger, Manager
Bureau of Transportation
Systems Research

Enclosure

RH:EP:jts

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TO Memorandum to Record

MEMORANDUM

FROM Edward PennellSUBJECT Highway DelineationDATE 1/24/89TELEPHONE NO. 2-4718

This is a record of observations made and facts gathered about delineation on New Jersey Department of Transportation highways. The field work upon which this report is based was done at various times from 1986 to 1988.

Edward Pennell
Assistant Engineer
Bureau of Transportation
Systems Research

EP:jts

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Abstract

Permanent and temporary delineation techniques in use on New Jersey State Highways are reviewed in this report. This is an interim report which is a step toward the development of delineation guidelines.

This is a report of a survey of field sites of delineation use. The choice of sites that were photographed was based on recommendations from Department of Transportation professionals and from knowledge of demonstrations of special delineation methods.

Included are identification of issues involved with different delineation treatments and the subjective appearance of both individual delineation treatments and combinations of delineation treatments. Some mention is made of each type of delineation known to exist. This survey served as one of several ways used to identify delineation issues (areas of uncertainty of Department policy). The guideline project will attempt to resolve these issues and develop a written consensus for roadway delineation.

Introduction

Roadway delineation consists of all the pavement striping, reflectors, and other devices used to indicate to drivers both roadway alignment and the intended travel path on the roadway. Since the early part of the century, delineation has played an important role in highway safety and performance. Since the first use of painted traffic stripes, many additional devices and treatments have been developed to increase the drivers' comfort and performance especially under adverse conditions including nighttime driving, rainy nights, and complex construction zones. A review was made of the present field use of delineation on highways owned and maintained by the New Jersey Department of Transportation. This report is a summary of observations of the present field use of delineation that relates to unusual or controversial practices (issues). Some issues were discovered due to the field survey while other issues were discovered through other project activities. The two general areas included in this field survey are permanent delineation and temporary delineation for construction and maintenance activities.

I. PERMANENT DELINEATION

A. Pavement Markings

The simplest and also most effective type of delineation is pavement striping. This is used on all State Highways in New Jersey. Far from being merely ordinary paint, pavement markings are composed of sophisticated formulations of materials which provide reflectance for visibility of the markings at night when illuminated by automobile headlights, as well as daytime visibility. Several different marking materials are used for applying the stripes to the road. The three major types are paint, epoxy, and pavement marking tape.

1. Paint

The paint utilized by the New Jersey DOT consists of an alkyd and chlorinated rubber vehicle with a pigment and is combined with glass beads at the point of roadway application. The glass beads provide night reflectance. Of the three major marking materials, the paint is the cheapest but also has the shortest life, sometimes fading from view in less than four months, according to the long-life pavement marking committee.

2. Epoxy

Epoxy-based markings are composed of epoxy resin as a base with pigment added. This marking material hardens by an internal chemical reaction and does not contain solvents to be given off to the atmosphere as does paint. Current Department specifications require the epoxy pavement markings to be hardened to a no-tracking condition in a maximum of 8 minutes. The specifications also require a daily 500-ft. long test strip for each striping machine to verify the no-tracking requirement. The use of the epoxy pavement markings is similar to paint in that glass beads mixed in with or dropped onto the material at the point of application provide night reflectance. The epoxy-based markings, while being more expensive than paint, are expected to last for at least two years under even the most severe wear conditions. In the past there have been questions about the durability of the reflectance of the epoxy markings over the long term. The epoxy markings have recently been installed as an evaluation effort for the Department Materials Committee. They will probably come into more widespread use if the results of this evaluation are positive.

3. Tape

Preformed pavement marking tape is a manufactured product which is attached to the pavement with adhesive. This tape is impregnated with reflective glass beads during manufacture. Pavement marking tape is commonly used for transverse markings such as stoplines, but only at a few demonstration sites has this method been utilized for longitudinal markings. There have been some problems with the durability of the reflectance of marking tape and as it is the most expensive method of

applying pavement markings, it is not in widespread use by the In New Jersey DOT. There is a demonstration of 3M's Stamark 350A pavement marking tape in progress on Rt. 280 where the manufacturer is providing a four-year replacement warranty. The use of pavement marking tape may come into wider use if this demonstration is successful.

4. Striping Configurations

The striping configurations used on State Highways conform to the Manual on Uniform Traffic Control Devices (MUTCD). Most striping is applied with a four-inch width. Gore lines which divide traffic at ramps are 8 inches in width and sometimes include cross-hatched areas between the channelizing lines. When dashed lines are used to divide traffic where passing is permitted, a 10-ft long stripe with a 30-ft gap between stripes is the dimension of this treatment. Generally, the use of pavement markings is straightforward and doesn't confuse drivers.

Interchange ramps may have special delineation needs depending on the presence of curbing on the ramps. Ramps onto limited-access roads are usually not treated with painted lines when concrete curbs are present. The curbs have some delineation value but can be a potential hazard to errant vehicles. Recently, the use of curbs on ramps for new construction has been discontinued; pavement striping is required on these ramps.(3) The problem of wet-night visibility of ramp delineation is now a more relevant issue.

5. Wet-Night Striping

Although pavement markings do provide good delineation, there are certain situations when pavement markings alone do not provide adequate guidance to drivers. Beaded paint pavement markings provide good delineation during the daytime when the paint is in good condition and at night when the beading is in good condition. However, on wet roads at night, even newly beaded paint markings have reduced visibility because of the reflection of light from the smooth wet road surface. During wet-night conditions roadway visibility is severely reduced and any delineation on the roadway that is not raised above the pavement surface is almost totally invisible. (1). If additional reflectorization is not provided either by raised pavement markers or roadside reflectorization, drivers experience difficulty maintaining their vehicles in the intended traffic lanes. (2).

The size of the glass beads normally specified for striping reflectorization is between approximately .008" and .030". The reflectivity of the striping may be related to bead size, especially if the road surface is wet. Larger size beads are thought to improve striping visibility at night in rainy conditions. Recently, as part of the epoxy long-life pavement marking demonstration on I-280, & section of striping with beads of approximately .040" to .065" diameter was installed. This product is being promoted as being able to provide delineation at night in rainy conditions. Large bead striping might

come into more widespread use if it provides a delineation benefit in wet-night conditions.

B. Raised Pavement Markers

Because pavement striping provides less delineation to drivers at night when roadways are wet then when dry, supplemental delineation systems may be beneficial. To address the problem of wet-night delineation, raised pavement markers (RPM's) were developed. These devices utilize a reflector shape which extends above the smooth film of water laying on the road surface and thus provides visibility to the driver in wet-night conditions using light reflected from headlights (2,4,5,6,7,8,9,10). Many types of RPM's have been developed over the past twenty years or so. The first widespread use of these devices was carried out in hot weather areas of the country with ceramic and polymeric markers attached directly to the pavement. This type of marker has proven very successful but is unsuitable for use in the northern U.S.A., including New Jersey, because snowplows remove these markers from the pavement. To eliminate the problem of removal of markers by snowplows, RPM's mounted in protective metal castings were developed and have come into widespread use in many States, including New Jersey (figure 1). In fact, over 100,000 snowplowable raised pavement markers (SRPM's) have been installed on New Jersey state maintained roads. These markers can provide a valuable delineation function during wet conditions at night and also supplement painted markings at night when the pavement is dry (figure 2). The markers provide information to the driver about roadway geometry at a distance greater than possible with pavement striping. This has been found to improve driver performance (8,10,11,12,13,14)

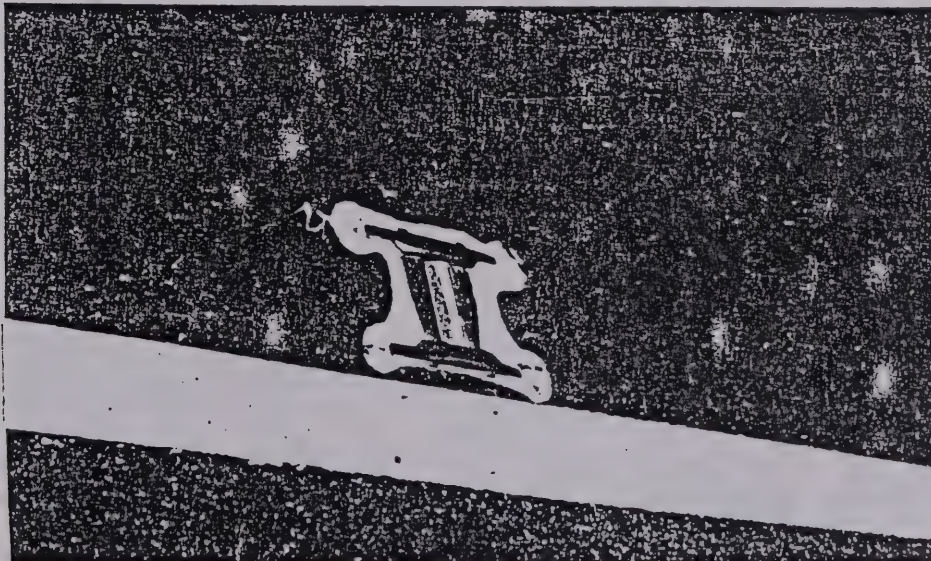


Figure 1 Snowplowable
Raised Pavement Marker (SRPM)

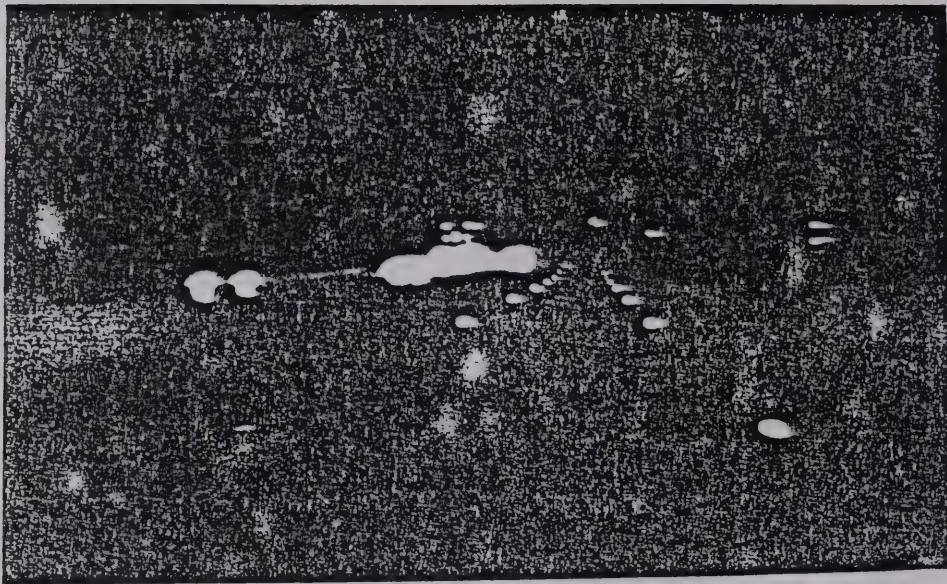


Figure 2 SRPM's at night

Although various makes and models of Snowplowable Raised Pavement Markers (SRPM's) have been investigated, in New Jersey, Stimsonite products model 96 and 96 "low-profile" are used almost exclusively. Durability of the reflective insert has been in question and new installations have recently been temporarily suspended due to a lack of agreement as to the cost-effectiveness of SRPM's (15). There is an extremely high variation in the amount of wear and damage to SRPM's around the state, with some sites having little or no damage. However, even at high damage sites a small amount of residual reflectivity does provide information to motorists. Prior to the suspension of SRPM installations, they were proposed to be installed on all limited access highways, heavily trafficked roads, and on other roads, at high accident frequency locations as determined by the Bureau of Traffic Engineering and Safety Programs. Not all limited access highways have been treated with SRPM's, due to the recent decision to reduce SRPM installations.

Practices relating to spacing and placement of RPM's have been developed by combining existing standards, research results, and field experience. The markers are mounted at 80, 40, and 20-foot intervals on the road, as a supplement to painted lines. The 80-foot spacing is used on straight road sections, 40-foot spacing is used on curves, and 20 foot spacing is used on gores at exit ramps. The markers are placed in line with lane skip lines in the gaps between the painted marks. RPM's are placed between double center lines. However, they may be offset a few inches laterally from edge lines to minimize accidental painting of the

markers. RPM's are not normally used to supplement right edge lines except where hazards are present adjacent to the roadway edge (6,16,17).

Some raised pavement markers have been painted over by mistake during road striping operations. Field observations have indicated that equipment meant to interrupt paint application at marker locations is not working consistently. Some installations have been made to be slightly offset from the painted line to help alleviate the problem of painted reflectors. This offset can, however, have the unwanted effect of reducing the width of pavement available for traffic between the delineation markings.

C. Center Barrier Delineators

Concrete median barriers are in widespread use on major highways and provide daytime guidance to drivers as well as physical separation of traffic. However, the concrete barriers can be made more visible at night by the use of a reflectorized treatment. Barrier delineators are not in use except for experimental installations, including one on Route 1 near Trenton. At this site, the top-mounted barrier delineators do help to make the barriers more visible to drivers at night (6) (figure 3). Previous research recommended an acrylic cube-corner reflector mounted on a flexible polymeric base and glued to the top of the barrier (18). Recent Department research into center barrier reflector spacing found an 80-ft. spacing to be optimum for most roadway geometrics; reduced spacing might be useful on curves where sight distance is limited.

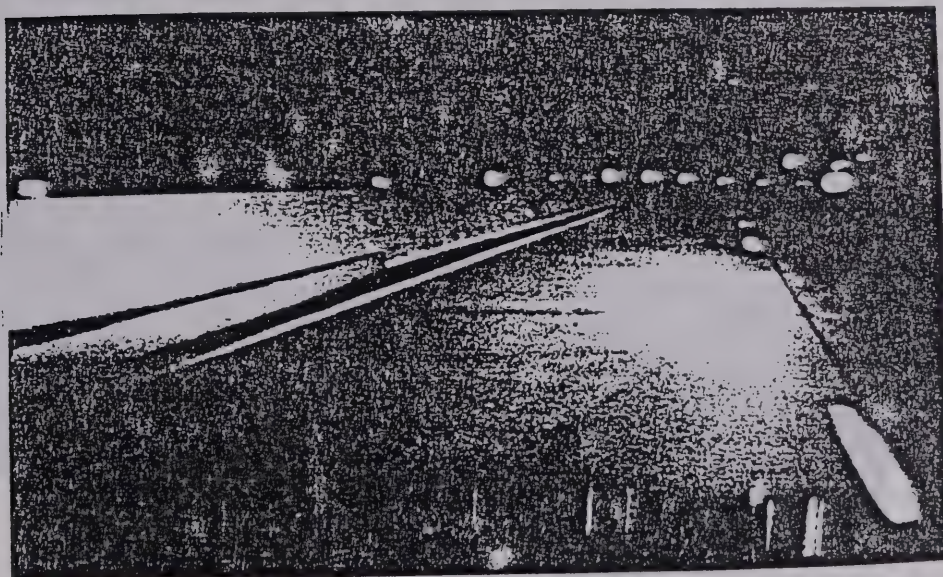


Figure 3 Center Barrier
Delineators at Night

D. Guiderail Delineators

Guiderail delineators are a way of making guiderails more visible to drivers. From a research study, guiderail delineators utilizing a flexible mounting system and a special appearance have been identified as the best method of delineating guiderail. Several experimental and demonstration installations of guiderail delineators have been made including a seven mile long installation on I-295. As they are mounted at a spacing of 80 feet on tangents and 40 feet on curves, they provide excellent information as to the location of the guiderail at night and do have some effect on the driver's view during daylight hours (figure 4). The delineators do seem to identify the guiderail by their different spacing and appearance from post delineators rather than giving the appearance of only post delineators which might deceive drivers into attempting to pull off the road into what may seem to some drivers to be an open space between the delineators. Both center barrier delineators and guiderail delineators provide wet-night delineation, although the offset location and greater height of these treatments above the roadway means that they provide only longer-range driver guidance rather than the closer range driver control provided by raised pavement markers (19).

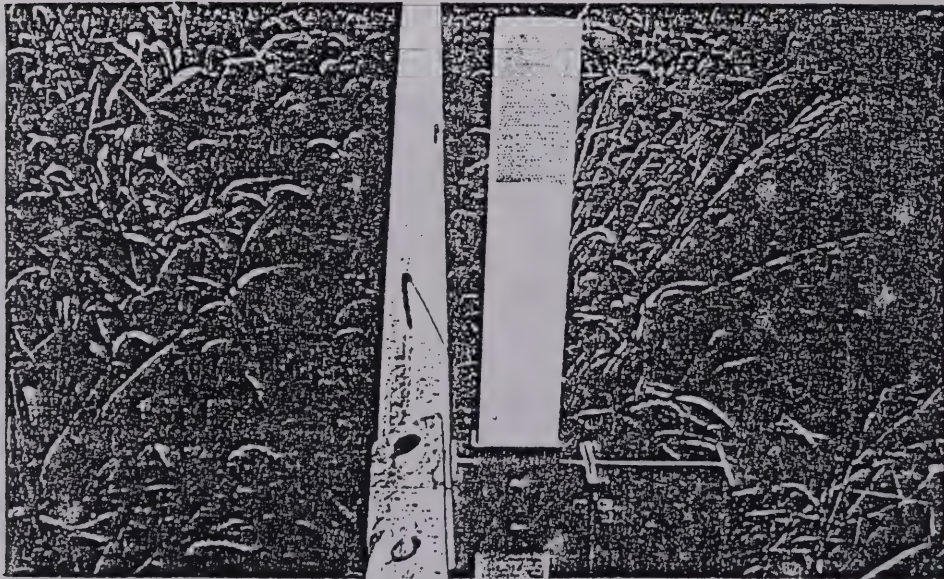


Figure 4 Guiderail Delineator

E. Post Mounted Delineators

Post mounted delineators also provide guidance to drivers during hours of darkness and inclement weather conditions (Figure 5). Post mounted delineators are commonly used throughout the State as they are one of the older methods of roadside delineation. In New Jersey, post delineators are generally mounted from 2 to 6 feet from the pavement edge and are supposed to have a height of 4 feet, in conformance with the MUTCD, however, some delineators have been struck by vehicles which affects their height, location, and performance. Reflective elements are white in color when used on the right of traffic and yellow when used on the left of traffic.

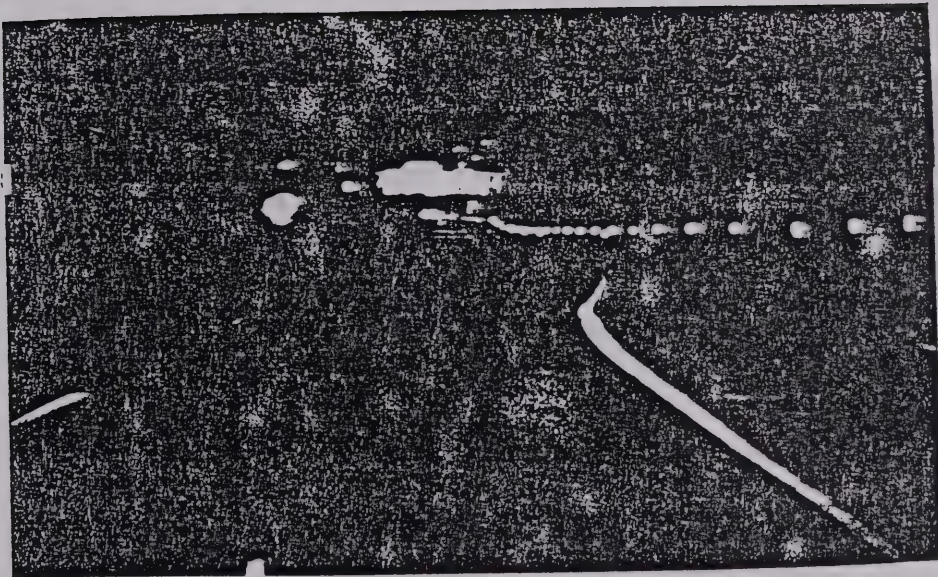


Figure 5 Post Mounted
Delineators at night

A new development in the use of post-mounted delineators in New Jersey is the recent introduction of flexible post-mounted delineators which can withstand vehicle impacts and continue to provide delineation. Flexible delineators have been installed in locations where post-mounted delineators have sustained repeated vehicle impacts. These flexible delineators are made from a relatively flat shaped polymeric material with reflective sheeting attached near the top of the post. The traditional rigid post delineators consist of a steel u-channel usually topped by an acrylic cube corner reflector, except at interchanges where reflective sheeting is used to reduce vandalism according to the Sign Shop.

F. Chevron Signs

Although chevron signs are not always thought of as delineators, a succession of the chevron signs provides guidance to drivers about roadway alignment similar to traditional delineators. On relatively sharp curves and some highway ramps, chevron signs are being used as a form of delineation. The advantages of the chevron treatment are greater height and a directional message. These signs assist drivers with curve identification and also improve speed and steering performance approaching and through curves (20).

G. Combinations of Delineation Methods

Delineation treatments are often used in combination. This generally increases the driver's comfort and driving performance. On Rt. 78 raised pavement markers, post-mounted delineators, and painted markings are all being used together. This provides a high level of guidance to drivers. A recent research study done by the Ohio State University found that pavement markings, raised markers, and post delineators used together provided the greatest curve detection distance on rural unlighted highways (9).

An advantage of both post-mounted delineators and guideway delineators is that they both extend above the surrounding environment and are visible when roads and roadsides are snow covered, when other methods of delineation are ineffective (3,5,6,8,9,11). Guideway delineators provide longer range guidance to motorists as do post-mounted delineators. Post-mounted delineators should be eliminated when guideway delineators are present.

II. TEMPORARY DELINEATION

When reconstruction of roads causes lane closures and redirection of traffic, means are required to provide proper guidance for traffic moving at a reasonable speed through construction areas. There are many different types of devices and treatments that are used to delineate intended travel paths in construction zones. Very noticeable are channelizers such as barrels (sometimes supplemented with vertical tail panels) and traffic cones. Concrete barriers and barricades are used as channelizers. When indicating lane closures, these devices are often supplemented by signs and illuminated arrow boards. Striping and raised pavement markers are used on the pavement in construction zones to give drivers a definite boundary of traffic lanes and roadway edges. All of these delineation methods used together provide information to the driver for the negotiation of construction zones.

A. Channelizers

The task of alerting motorists to a change in the normal roadway alignment is difficult because traffic often flows in set paths which are resistant to change. While advance publicity and warning signs do prepare many drivers to expect changes in traffic paths, the real job of indicating lane closures falls to channelizing devices. The most critical area for traffic in any construction zone is the "taper" area where traffic is forced out of its regular lanes and into the restricted or diverted construction zone roadway. This taper is as shallow as practicable with fairly close channelizer spacing of about 50-ft. for highways as per the MUTCD.

1. Barrels

Barrels are often used for construction zone lane closures. Barrels are usually used outside of the lane taper areas where the more massive type III barricades are specified. The barrels are made from orange plastic with reflective sheeting for night visibility and have one or more flat sides to prevent them from rolling around if knocked over. Barrels are ballasted with sandbags to increase their stability. In some ways barrels do provide superior channelization than barricades because they are shaped as a simpler more vertical unit which increases the driver's depth perception (Figure 6). Barrels are sometimes mistakenly spaced further apart than the 100-ft. intervals specified by the MUTCD for tangent lane closures outside of taper areas.

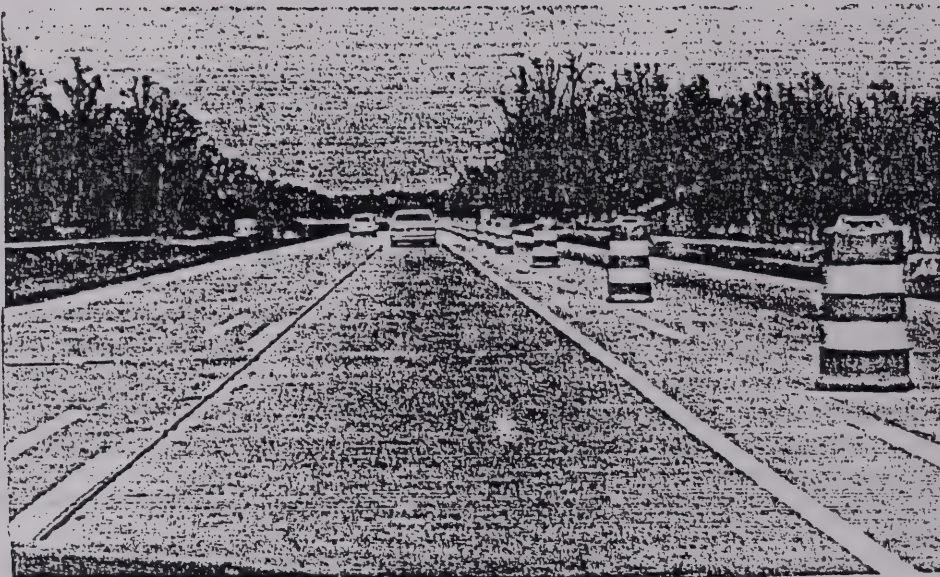


Figure 6 Barrels for Lane Closure

2. Vertical Tall Panels

Barrels can be equipped with a supplementary device called a vertical tall panel which is mounted on top of the barrel and provides extra height for better visibility. The tall panels are beneficial in taper areas. The four foot high panels mounted on three foot high barrels results in a seven foot total height which is higher than type III barricades. These panels are about eight inches wide and are covered with reflective sheeting employed in a diagonal hazard pattern.

When equipped with vertical tall panels, the barrel-tall panel combination provides the height necessary to warn drivers in advance of lane closures in spite of crests and leading vehicles. These tall panels provide a visual representation of distance and perspective, especially at night (21) (figure 7).

3. Cones

Cones are another form of channelizer that are usually only used for road closures of one day or less because they are the smallest, least visible type of channelizing device (figure 8). Motorists have been observed disregarding cones, especially on high speed roads. There is a difficulty created when cones blow over in the wind caused by traffic. This increases motorist disrespect for the cones, possibly originated by their low height. When cones are used for road closures, often the specified spacing for the cones is not followed which may further deteriorate performance by motorists who may not clearly see the intended travel path. This is especially evident at exit and entrance ramps on limited access highways. However, cones are the cheapest and most convenient type of channelizing device to store and place on the road.

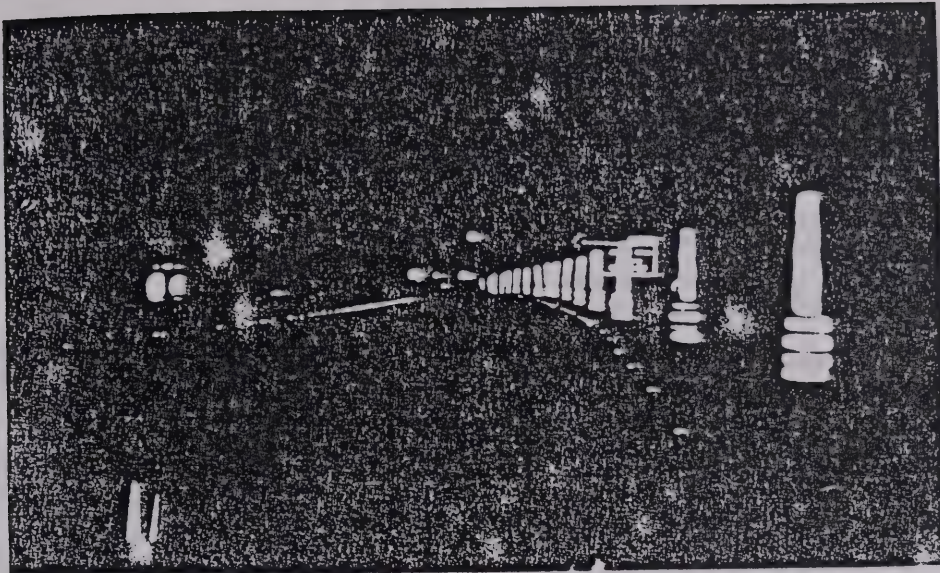


Figure 7 Vertical Tail panels on barrels at night with raised pavement markers



Figure 8 Cones for Lane Closure

B. Barriers

When clearances are narrow and drop-offs are present, concrete barriers provide a high level of protection for drivers and also for construction workers. These barriers provide a channelizing effect but their visibility at night is low. Barriers can be delineated by attaching 6"x12" reflective sheeting panels to the top of the barrier. This method is in widespread use in construction zones in New Jersey.

C. Barricades

In New Jersey, type III barricades are used as channelizers in almost all taper areas for construction closures of more than a few days duration. These devices are approximately four feet wide and five feet tall in current practice and are constructed of a breakable plastic material to minimize hazards to impacting vehicles and drivers. The type III barricades do have a high visibility on the roadway in the critical taper areas, however, due to their large width, the view of successive barricades can be partially blocked by nearer barricades and thus they provide little distance cue (22) (Figure 9). One example of this effect is the use of reflective arrow signs on the barricades to show the intended lateral movement of traffic; the view of the signs is often blocked by other barricades and the effectiveness of the signs is reduced. Sometimes narrow shoulders and lack of lateral clearance prohibit the use of the type III barricades as channelizers. In these instances, the tall vertical panel device mounted on barrels provides an alternate method of delineation for "taper" areas.



Figure 9 Barricades used as channelizers

D. Temporary Pavement Markings

In addition to channelizing devices, pavement markings and temporary raised pavement markers (TRPM's) are usually used in construction zones to indicate the lanes available to traffic. Pavement stripes are most often applied with temporary pavement marking tape which is usually easy to remove at the end of the construction project (21,23). Tape provides good daytime and nighttime delineation. It is, however, expensive. Also, when changes are made to the construction area traffic patterns, pavement markings are not always changed appropriately to match the new geometry (figure 10).

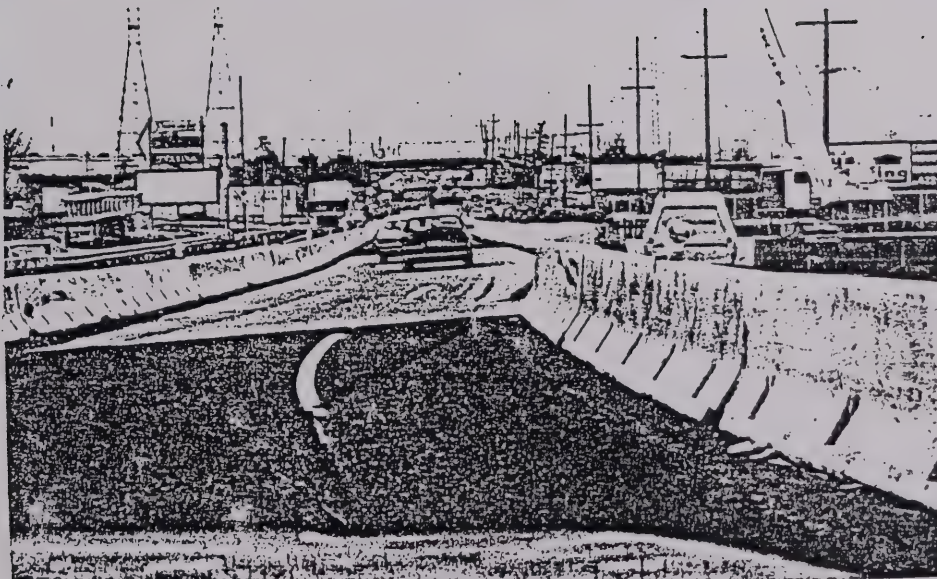


Figure 10 Improper Temporary pavement markings.

E. Temporary Raised Pavement Markers (TRPM's)

Temporary raised pavement markers are currently used as a supplement to marking tape in some construction zones. TRPM's are used in construction zones that have poor geometry, as determined by Traffic Engineering, and provide extra delineation especially on rainy nights (21,22,23). These raised markers include retroreflective elements which provide the desired night visibility. These devices are used in situations identified by the Bureau of Traffic Engineering and Safety Programs.

Another use for TRPM's has recently been tried in New Jersey. TRPM's were used alone as a complete marking system. Spacing of the markers was 6-feet when they were used to simulate a solid line. This method of temporary delineation has a cost advantage over the expensive temporary pavement marking tape. As part of this Department research project, traffic performance was found to improve when TRPM's were used as a paint replacement. This method of delineation has been accepted for use in construction zones where designated by the Bureau of Traffic Engineering and Safety Programs, at their discretion.

DISCUSSION

This report is not meant to be an exhaustive and comprehensive evaluation of all delineation existing on the State Highway system, but rather provides a general overview of problems and issues associated with delineation as seen on the New Jersey State Highway system. The sites that were observed and photographed were those that were recommended as being of some special interest by various Department of Transportation personnel. An attempt was made, however, to include at least some information on all categories of delineation. This report is useful as an informal summary of the technological limits of delineation and some improvements that are being developed.

From this survey, driving at night in rainy conditions has been found to need improvement. The Department is attempting to develop delineation for wet, nighttime driving conditions, namely RPM's. This work will improve driving conditions at night. Nighttime driving has been identified as a more dangerous driving environment. (5)

One other area of effort is the provision of delineation at a lower initial and lower maintenance cost. Examples of this include long-life pavement markings and flexible post delineators.

It is evident that there is a need to emphasize the importance of all types of delineation to designers, construction crews, and maintenance people to insure well planned and well executed roadway safety systems.

ACKNOWLEDGEMENTS

The author would like to thank the following individuals and groups for their assistance.

A.W. Roberts for technical and editorial assistance. Sanat Bhavsar for his extensive field work upon which this report is partially based. John Powers, Thomas Davis, and John Campl, for technical information.

Carey Younger of the Bureau of Transportation Structures Research for information on long-life pavement marking materials. John Semler of the Bureau of Traffic Engineering and Safety Programs for information on SRPM's and coordination of field inspections of SRPM's. Robert Waldorf of Traffic Engineering and Safety Programs for information on construction zone delineation.

LIST OF REFERENCES

1. Blaauw, Gerard J. and Padmos, Pieter, Nighttime Visibility of Various Types of Road Markings; A Study Durability, Including Conditions of Rain, Fog and Dew, SAE Technical Paper No. 820412, Society of Automotive Engineers, 1982.
2. Traffic Control Devices Handbook, FHWA, 1983.
3. Roadway Design Manual, NJDOT.
4. Shepard, Frank, Evaluation of Raised Pavement Markers for Roadway Delineation During Fog, Virginia Highway and Transportation Research Council, October, 1976, VHTRC 77-R21.
5. Vanstrum, Robert C. and Lander, John C., The Dark Side of Driving, Transportation Quarterly, 38, (4), October 1984, Philadelphia, PA.
6. Delineation Conference Executive Summary, FHWA, November 1977, FHWA-TS-77-217.
7. Roberts, A.W. and Jagannath, M.V., Evaluation of Snowplowable Raised Reflective Pavement Markers In New Jersey, NJDOT, November, 1976.
8. Schwab, R., and Capelle, D., Is Delineation Needed? ITE Journal, May 1980, Public Roads, December, 1979, Vol. 3, No. 3
9. Rockwell, T.H., and Smith G.L., Recommended Delineation Treatments at Selected Situations on Rural State Highways FHWA/OHIO - 85/001, June, 1984.
10. Schreuder, D.A., The Visibility of Carriageway Markings on Wet Roads, Central Laboratories of Bridges and Highways, France, TRR Laboratory, IRRD 108568.
11. Nemeth, Z.A. et. al., Effect of Delineation System on Curve Detection Distances under Simulated Rural Nighttime Driving Conditions, Ohio DOT #EES-627.
12. Mallowney, W.L., Effect of SRPM on Traffic Performance, NJDOT, June 1982.
13. Zwahlen, H.T., Optimal Placemet of Reflective Markers, Ohio DOT, August 1985.
14. Niessner, Charles W., RPM's at Hazardous Locations, FHWA, December 1984, FHWA-TS-84-215.
15. Trolano, Donna, Memorandum of Record, "Future of RPM Program", NJDOT, February 11th, 1988.

16. Dayton, Edwin W., Roadway Design, NJDOT, Letter to FHWA "SRPM Guidelines", August 13th, 1982.
17. Bicycle Compatible Roadways - Planning and Design Guidelines NJDOT, 1982.
18. Mallowney, William L., Center Barrier Visibility Study, NJDOT, January, 1978.
19. Allen, Wade R., Reflectorization of Curves, Systems Technology Inc., Hawthorne, CA, TRB 1984 Annual Meeting Presentation.
20. Zador, Paul et. al., Effects of Chevrons, Post-Mounted Delineators, and Raised Pavement Markers on Driver Behavior at Roadway Curves, Insurance Institute for Highway Safety, TRB 1987 Annual Meeting Presentation. 1987.
21. Davis, Thomas D., Construction Zone Delineation, TRR 811, 1981.
22. Donaldson, Gerard, Traffic Control for Work Zones on Freeways, Center for Auto Safety Report No. DOT-1-86-05, February, 1985.
23. Niessner, Charles W., Construction Zone Delineation (Raised Pavement Markers), FHWA, June 1978, FHWA-TS-78-222.

APPENDIX D
DELINEATION PRIORITIES QUESTIONNAIRE

TO Those Listed Below

MEMORANDUM

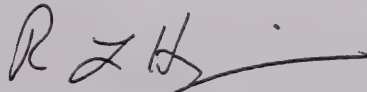
FROM Richard L. HollingerSUBJECT Delineation Priorities DATE 4/15/86 TELEPHONE NO. 530-3613
Questionnaire

The Bureau of Transportation Systems Research is working on a project to develop guidelines for highway delineation. We intend to form guidelines through a consensus reached by a committee of experienced professionals on the subject of delineation. You were recommended as a questionnaire respondent based on your expertise and your concern for furthering the goal of transportation safety in New Jersey.

Your participation in the project will entail answering the attached questionnaire to obtain your individual and exclusive input and getting together in a follow-up meeting for a survey summary and discussion.

Enclosed is a preliminary questionnaire which needs your prompt response. Your comments or any additions you would like to make to the subjects covered in the questionnaire would also be appreciated. We will be calling your office within the next week to fix a date for the follow-up meeting and to verify your participation.

Please contact either Sanat Bhavsar or Mike Roberts at 530-3613 if you have any questions. Your response to the questionnaire by April 22, 1986 will be appreciated. Thank you.



Richard L. Hollinger, Chief
Bureau of Transportation
Systems Research

LIST

R. Hobson
M. MacKenzie
C. Rebbeck
O. Abbott
F. Wilkinson
H. Burton
J. Thompson
M. Harris
P. Lenk

R. Kulvicki
R. Malinoski
D. Troiano
R. Reinke
M. Jagannath
S. Salvatini
R. Balgowan
R. Andrejczik
P. Riscica

R. Johnson
M. Lemmo
P. Yanucil
J. Walker
W. Chaty
T. Swedo
G. Marr
A. Eisdorfer

TO Those Listed Below

MEMORANDUM

FROM Richard L. HollingerSUBJECT Delineation Priorities DATE 3/19/86 TELEPHONE NO. 530-3613
Questionnaire

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Please contact either Sanat Bhavsar or Mike Roberts at 530-3613 if you have any questions. Your response to the questionnaire by March 27, 1986 will be appreciated. Thank you.



Richard L. Hollinger, Chief
Bureau of Transportation
Systems Research

LIST

E. Dayton	J. Vanelli	G. Keller
J. Datz	F. Lovett	A. Alaimo
C. Goessel	N. Tuz	N. Cifelli
C. Takacs	J. Dunn	J. Pittman
N. Deitch	D. Andres	S. Sikorski
J. O'Brien	R. Tomlinson	E. Nolan
J. Bodnar	M. Kjetsaa	J. Ertle
R. Waldorf	G. Lobman	S. Bosco
J. Semler	W. Steever	W. Cunningham
G. Bodholt	K. Erick	R. Micai
W. Anderson	J. Croteau	R. Leahey
R. Wokoun	C. Younger	O. Kee

NAME: _____

Bureau: _____

Date: _____

DELINEATION PRIORITIES QUESTIONNAIRE

The Division of Research and Demonstration in cooperation with a committee of higher level professionals is reviewing highway delineation guidelines for New Jersey highways.

We would like to better understand your thoughts about delineation needs and practices in the state of New Jersey. Your responses will help us to determine the priorities that Department Managers and professionals put on delineation of highways and thus help us focus our efforts to recommend guidelines. Please help us improve our transportation systems for the motorists.

The following definition of delineation is provided since the term is frequently used.

Delineation: An enhanced outline of highway features which can help drivers find and follow lanes, contours, curves and alignments.

Please feel free to comment after each question.

First, some general questions to help us get insight into how you view the scope of the problem.

1. Compared to daytime, nighttime visibility (Check one):

- (a) Could be improved. ☐
- (b) Is not different. ☐
- (c) Is better. ☐

2. Nighttime driving conditions could be improved by NJDOT (Check as many as apply):

- (a) By introducing more illumination on highways. ☐
- (b) By increasing roadway delineation. ☐
- (c) By increasing roadside delineation. ☐
- (d) By modifying roadway and roadside design. ☐
- (e) By painting traffic lines more often. ☐
- (f) Cannot be improved further. ☐
- (g) By other means, please specify. ☐

3. The present use of delineation systems in the state of New Jersey is:

- (a) More than adequate. ☐
- (b) Adequate. ☐
- (c) Good but can be improved. ☐
- (d) Inadequate. ☐
- (e) Nothing can be done
that has not already been done. ☐

The following questions will aid us in understanding which devices and treatments can help most.

4. Here is a list of delineation devices. Mark if you have seen them while driving at night and how applicable you think they are for the delineation of all New Jersey highways, considering the needs in the next 15 to 20 years.

Device	Have Seen	Have Not Seen	Not Sure	Will Have Major Appli- cation	Minor Appli- cation	No Appli- cation	Don't Know
A. ROADWAY DELINEATION FOR HIGHWAYS:							
1. Pavement Marking, Paint	☐	☐	☐	☐	☐	☐	☐
2. Snowplowable Raised Pavement Markers	☐	☐	☐	☐	☐	☐	☐
3. Permanent Striping Tape	☐	☐	☐	☐	☐	☐	☐
B. ROADSIDE DELINEATION FOR LOCAL RURAL ROADS, TWO LANE, TWO WAY, AND MULTILANE, <u>UNDIVIDED</u> HIGHWAYS:							
1. Post Delineators	☐	☐	☐	☐	☐	☐	☐
2. Guiderail Reflectors	☐	☐	☐	☐	☐	☐	☐
3. Chevron Alignment Signs	☐	☐	☐	☐	☐	☐	☐
4. Curb Markings	☐	☐	☐	☐	☐	☐	☐
5. Colored Pavement or Contrasted Shoulders	☐	☐	☐	☐	☐	☐	☐
C. MEDIAN DELINEATION FOR <u>DIVIDED</u> HIGHWAYS:							
1. Snowplowable Raised Pavement Markers	☐	☐	☐	☐	☐	☐	☐
2. Center Barrier Delineators	☐	☐	☐	☐	☐	☐	☐
3. Post Delineators	☐	☐	☐	☐	☐	☐	☐
4. Guiderail Reflectors	☐	☐	☐	☐	☐	☐	☐

Device	Have Seen	Have Not Seen	Not Sure	Will Have Major Appli- cation	Minor Appli- cation	No Appli- cation	Don't Know
D. TEMPORARY DELINEATION FOR CONSTRUCTION ZONES ON HIGHWAYS:							
1. Barricades, Types I, II and III	☐	☐	☐	☐	☐	☐	☐
2. Cones	☐	☐	☐	☐	☐	☐	☐
3. Tubes (18" high with broad base)	☐	☐	☐	☐	☐	☐	☐
4. Barrels	☐	☐	☐	☐	☐	☐	☐
5. Tall Panels (on barrels)	☐	☐	☐	☐	☐	☐	☐
6. Vertical Panels	☐	☐	☐	☐	☐	☐	☐
7. Temporary Raised Pavement Markers	☐	☐	☐	☐	☐	☐	☐
8. Temporary Tape	☐	☐	☐	☐	☐	☐	☐
9. Steady Burn Lights on Barricades, Barrels or Barriers	☐	☐	☐	☐	☐	☐	☐
10. Flashing Lights	☐	☐	☐	☐	☐	☐	☐
11. 5" x 10" Reflector- ized Plate on Concrete Barriers	☐	☐	☐	☐	☐	☐	☐
12. Center Barrier Delineators	☐	☐	☐	☐	☐	☐	☐
E. OBJECT MARKERS FOR HIGHWAYS:							
1. 18" Yellow or Black Diamond Panel with Nine Yellow Reflectors	☐	☐	☐	☐	☐	☐	☐
2. 6" x 12" Panel with Three Reflectors	☐	☐	☐	☐	☐	☐	☐
3. 12" x 36" Vertical Panel with 45° Sloped Black and Yellow Stripes	☐	☐	☐	☐	☐	☐	☐

Device	Have Seen	Have Not Seen	Not Sure	Will Have Major Appli- cation	Minor Appli- cation	No Appli- cation	Don't Know
4. 18" Diamond Shaped Red Reflectorized Panel with Nine Red Reflectors	☐	☐	☐	☐	☐	☐	☐
F. Any other type of delineation device (Please mention it.)	☐	☐	☐	☐	☐	☐	☐

The following questions deal with your specific responsibilities and will help us understand your involvement with delineation.

5. My involvement with highway delineation:

- a. Was more than a year ago. ☐
- b. Is current. ☐
- c. Could be in the near future. ☐
- d. Not involved, but interested. ☐

6. Following is a list of items concerning the subject of highway delineation that could be relevant to your responsibility. Please estimate the percentage of your time spent on the work related to the following items.

	30%+	20%- 30%	10%- 20%	5%- 10%	0%- 5%
a. Installation and spacing	☐	☐	☐	☐	☐
b. Placement	☐	☐	☐	☐	☐
c. Replacement and maintenance	☐	☐	☐	☐	☐
d. Selection of a device or devices in combination	☐	☐	☐	☐	☐
e. Physical characteristics of devices such as: size, reflectivity, color, intensity, and durability.	☐	☐	☐	☐	☐

7. The following geometric, environmental and traffic situations and conditions could warrant additional highway delineation. Please choose the relative importance of additional delineation for each of the situations.

	Of Great Impor	Of Some Impor	Of No Impor	Not Appli- cable
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Special Geometric Situations:

a.	Horizontal curve, left	☐	☐	☐	☐
b.	Horizontal curve, right	☐	☒	☐	☐
c.	Vertical curve, crest	☐	☐	☐	☐
d.	Vertical curve, sag	☐	☐	☐	☐
e.	Bridges: approach, deck and end	☐	☐	☐	☐
f.	Underpass of a crossing road	☐	☐	☐	☐
g.	Overpass of a crossing road	☐	☐	☐	☐
h.	Exit and entry points, gore areas on limited access highways	☐	☐	☐	☐
i.	Multilanes - four or more lane highways	☐	☐	☐	☐
j.	Approaches to intersections and points of intersection	☐	☐	☐	☐
k.	Merges and lane drops	☐	☐	☐	☐
l.	Cross overs from express to local and vice versa	☐	☐	☐	☐
m.	Other, please note.	☐	☐	☐	☐

Environmental Situations:

Daytime:

n.	Rain	☐	☐	☐	☐
o.	Snow	☐	☐	☐	☐
p.	Fog	☐	☐	☐	☐
q.	Dry, normal weather	☐	☐	☐	☐

		Of Great Impor	Of Some Impor	Of No Impor	Not Appli- cable
<u>Nighttime:</u>					
r.	Rain	☐	☐	☐	☐
s.	Snow	☐	☐	☐	☐
t.	Fog	☐	☐	☐	☐
u.	Dry, normal weather	☐	☐	☐	☐

Other Situations:

v.	Sites with high number of accidents	☐	☐	☐	☐
w.	High volume of traffic	☐	☐	☐	☐
x.	Low volume of traffic	☐	☐	☐	☐
y.	—	☐	☐	☐	☐
z.	—	☐	☐	☐	☐

Comments:

Please return the completed questionnaire to:

Sanat Bhavsar
Bureau of Transportation Systems Research
New Jersey Department of Transportation
1035 Parkway Avenue, CN 600
Smith Building
Trenton, NJ 08625.

Or By Interoffice Mail to:

Sanat Bhavsar
Research
Herbert Smith Building

APPENDIX E
DELINEATION ISSUES QUESTIONNAIRE

AGENDA

<u>ACTIVITY</u>	<u>TIME</u>
1. Introduction	5 mins.
2. Presentation of questionnaire results	10 mins.
3. Questions?	10 mins.
4. Discussion of possible issues raised from questionnaire responses	30 mins.
5. Rating of Issues	10 mins.
6. Break	10 mins.
7. Solicitation of more issues seemed relevant	15 mins.
8. Next step in work plan	10 mins.
9. Closing remarks	5 mins.

Your input is always welcome.

Mike Roberts or Sanat Bhavsar
530-3613

Issues in Permanent Delineation

* 3 is the highest

	Is An Issue	Is not An Issue	Don't Know	Importance Rating Scale 1-3*
1. Pavement Marking, Paint				
Wet Night Paint (Research Project)	☐	☐	☐	☐
Extended Life Pavement Marking, e.g., thermoplastics and epoxy; need guidelines and warrants.	☐	☐	☐	☐
2. SRPM - Some guidelines are available, need more procedural guidelines.				
(a) Quality installations and maintenance	☐	☐	☐	☐
(b) Warrants - when to use them	☐	☐	☐	☐
(c) Difference from MUTCD Guidelines	☐	☐	☐	☐
(d) Adhesives (Research Project)	☐	☐	☐	☐
3. Post Delineators				
(a) Flexible Post - guidelines	☐	☐	☐	☐
(b) Total reflectorization of the post?	☐	☐	☐	☐
(c) Wet night delineation	☐	☐	☐	☐
(d) Maintenance guidelines	☐	☐	☐	☐

Is An Issue	Is not An Issue	Don't Know	Importance Rating Scale 1-3*
----------------	--------------------	------------	------------------------------------

4. Center Barrier Delineators

- | | | | | |
|--|--------------------------|--------------------------|--------------------------|--------------------------|
| (a) Spacing (Research Project) | ☐ | ☐ | ☐ | ☐ |
| (b) Warrants - where and when to use,
size, materials | ☐ | ☐ | ☐ | ☐ |
| (c) Method of installation | ☐ | ☐ | ☐ | ☐ |
| (d) Maintenance | ☐ | ☐ | ☐ | ☐ |

5. Chevron Alignment Signs

- | | | | | |
|------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| (a) Warrants | ☐ | ☐ | ☐ | ☐ |
| (b) Spacing, placement | ☐ | ☐ | ☐ | ☐ |
| (c) Maintenance | ☐ | ☐ | ☐ | ☐ |

6. Permanent Striping Tape

- | | | | | |
|--------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| (a) Warrants - when and where to use | ☐ | ☐ | ☐ | ☐ |
| (b) Placement | ☐ | ☐ | ☐ | ☐ |
| (c) Maintenance | ☐ | ☐ | ☐ | ☐ |

	Is An Issue	Is not An Issue	Don't Know	Importance Rating Scale 1-3*
7. Guiderail Delineators				
(a) Warrants (Research Project)	☐	☐	☐	☐
(b) Spacing	☐	☐	☐	☐
(c) Maintenance	☐	☐	☐	☐
8. Colored Pavement/Contrasted Shoulders?	☐	☐	☐	☐
9. Curb Reflectorization?	☐	☐	☐	☐

Issues in Temporary Delineation

	Is An Issue	Is not An Issue	Don't Know	Importance Rating Scale 1-3*
1. Barrels				
(a) Spacing on curves and exits	☐	☐	☐	☐
(b) Maintenance	☐	☐	☐	☐
2. Barricades (Type III)				
(a) Use of tall panels on barrels instead	☐	☐	☐	☐
(b) Use in transition zones and as channelizers	☐	☐	☐	☐
(c) Maintenance	☐	☐	☐	☐
3. Temporary Tape				
(a) Use of temporary raised pavement markers instead	☐	☐	☐	☐
(b) Warrants - when and where to use	☐	☐	☐	☐

	Is An Issue	Is not An Issue	Don't Know	Importance Rating Scale 1-3*
4. Cones? (Traffic Channelization)	☐	☐	☐	☐
5. Temporary Raised Pavement Markers				
(a) Warrants	☐	☐	☐	☐
(b) Spacing	☐	☐	☐	☐
(c) Maintenance	☐	☐	☐	☐
6. Flashing Lights (Warning Lights)				
(a) Warrants	☐	☐	☐	☐
(b) Spacing, placement	☐	☐	☐	☐
(c) Maintenance	☐	☐	☐	☐
7. Center Barrier Delineators				
(a) Use in place of steady burn lights	☐	☐	☐	☐
(b) Spacing on curves	☐	☐	☐	☐
(c) Maintenance	☐	☐	☐	☐

Is An Issue	Is not An Issue	Don't Know	Importance Rating Scale 1-3*
----------------	--------------------	------------	------------------------------------

3. 5" x 10" Reflectorized Plate on Concrete

Barriers, Barricades or Barrels

(a) Use in place of steady burn lights

☐	☐	☐	☐
--------------------------	--------------------------	--------------------------	--------------------------

(b) Warrants

☐	☐	☐	☐
--------------------------	--------------------------	--------------------------	--------------------------

(c) Maintenance

☐	☐	☐	☐
--------------------------	--------------------------	--------------------------	--------------------------

9. Vertical Panels?

☐	☐	☐	☐
--------------------------	--------------------------	--------------------------	--------------------------

10. Tubes? (18" high)

☐	☐	☐	☐
--------------------------	--------------------------	--------------------------	--------------------------

Object Markers?

1.

2.

APPENDIX F
DELINEATION ISSUE RESOLUTION QUESTIONNAIRE

TO List

MEMORANDUM

FROM R. HollingerSUBJECT Delineation Guidelines DATE 2/14/89 TELEPHONE NO. 2-4718
Questionnaire

Using the attached questionnaire, the Bureau of Transportation Systems Research is gathering information on how to resolve issues of delineation that were identified from a previous questionnaire.

Please answer this questionnaire with your professional opinions, and return to the Division of Research. In the questionnaire, an idea on how to resolve each issue has been given for your consideration and comments.

Any additions you would like to make to the subjects covered in the questionnaire would also be appreciated. We will be calling your office within the next week to verify your participation. Please contact either Mike Roberts or Ed Pennell at 292-4718 if you have any questions. Your response to the questionnaire by February 22nd will be appreciated. Thank you.

Richard L. Hollinger, Manager
Bureau of Transportation
Systems Research

Attachment

EP:RH:jts

N. Tuz	A. Roberts	C. Goessel
A. Mendola	M. Mackenzie	J. Semler
R. Tomlinson	D. Troiano	C. Younger
M. Kjetsaa	A. Alaimo	O. Kee
J. Pittman	R. Micai	S. Toth
R. Johnson	G. Keller	R. Leahy
D. Andres	J. Campi	J. Bodnar
N. Deitch	J. O'Brien	J. Vanelli
R. Waldorf	E. Nolan	T. Davis
S. Bosco		

Delineation Issue Resolution
Questionnaire No. 1

Pavement Striping and
Raised Pavement Markers

INSTRUCTIONS

1. Read each question and rate the importance of the issue. Use the following rating scale:

 - 0 = no importance
 - 1 = low importance
 - 2 = important
 - 3 = very important
 - ? = not familiar with the question
2. Read any background and the idea given as a potential response to the issue, and check one box indicating whether, in your professional opinion, you agree with the idea, you disagree with the idea, or that you don't know.
3. If you disagree with an idea mentioned as a possible answer to an issue, please give a reason.
4. Include any comments you may have.
5. At the end of each section add any issues you may have in mind.

DELINEATION ISSUES RESOLUTION QUESTIONNAIRE

A. PAVEMENT MARKINGS ISSUES:

1. Should cloverleaf interchange striping be changed?

IMPORTANCE OF QUESTION
SCALE 0 -3* OR ?

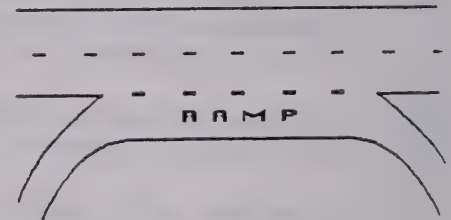
☐
4

*3 is the highest

A research project is being done to identify optimum striping patterns, however, the striping should be changed in the following ways while the project is active, as demonstrations.

Alternative 1: Place wide lines between the ramp and the main line (NCHRP 130).

AGREE DISAGREE DON'T KNOW

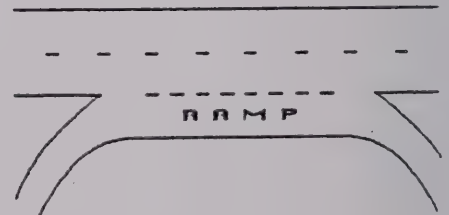
☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

Alternative 2: Decrease the gap to line ratio between the ramps and main line as allowed by the MUTCD.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS

3. Should dotted lines be placed in intersections to show turning paths when multiple turn lanes are used?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐
4

*3 is the highest

Idea: In accordance with section 3B-7 of the MUTCD, a dotted line should be used to extend markings as necessary through an intersection to guide vehicles through the turn where multiple left turn lanes are used



AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

4. Should long-life pavement markings (such as epoxy and permanent tape) be adopted?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐
4

*3 is the highest

A demonstration is in progress on Rt. 280 of the epoxy pavement marking system developed by the committee on long-life pavement markings and a commercial pavement marking tape.

Idea: If this demonstration shows adequate durability of the epoxy markings, they should be installed more extensively.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

5. On which roads should long-life markings be used, if adopted for general use?

IMPORTANCE OF QUESTION
SCALE 0 - 3*?

☐

*3 is the highest

4

Idea: Install the markings on all the roads recommended by the committee on long-life markings. These include limited access highways, and other roads with an AADT of greater than 25,000.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

6. If long-life pavement markings are adopted for use, should they be installed as soon as possible on existing already striped road surfaces or only as road resurfacing proceeds?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Despite other benefits of long-life pavement markings they usually cannot be applied on top of painted markings, and the old paint must be ground off the pavement when long-life markings are to be applied. This is an expensive, time-consuming process, and it creates a scar which drivers mistake for a line on wet nights.

Idea: Due to the disadvantages associated with grinding, avoid installation of long-life markings on existing previously striped pavements.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

7. Should large size glass bead wet-night striping be used on state roads?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Large size glass bead wet-night striping has a promising future potential. A demonstration is in progress on Rt. 280.

Idea: Adopt this method of striping for widespread use if field evaluations prove that it provides a valuable delineation benefit on both day and wet-nights.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

8. Please write any additional issues, problems, or ideas concerning "Pavement Markings."

B. PLACEMENT AND WARRANTS FOR RAISED PAVEMENT MARKERS (RPM'S):
ISSUES:

1. What RPM treatment should be used for approaching intersections?

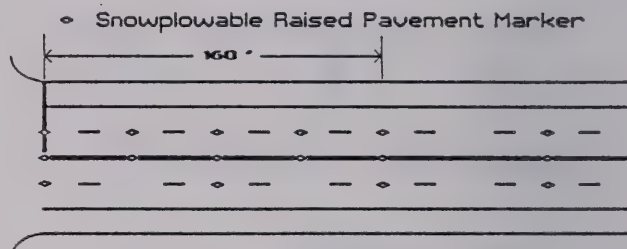
IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Idea: In accordance with section 3E-1 of the Traffic Control Handbook, reduce spacing to 40 ft. beginning 160 ft. from the intersection for traffic approaching the intersection and also for markers dividing two way traffic.



AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. Should RPM's be used on interchange ramps?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Idea: The RPM policy specifies that in general RPM's should not be used on right edge lines. Place SRPM's at 40 ft. intervals adjacent to ramp left edge lines but not on right edge lines.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

3. Should RPM's be used to identify special use lanes?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

RPM's are not very effective for providing coded identification for two-way center left turn lanes, center double yellow gore areas, and HOV lanes

Idea: Continue the simple standard line treatments as appropriate.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT;

OTHER COMMENTS:

4. When should SRPM'S be used to supplement right edge lines?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

The policy of the Department is to use SRPM's on right edge lines only under special circumstances where obstructions are near to the roadway edge such as: poles, walls, trees, etc. Also, the New Jersey DOT Bicycle Compatible Roadways Planning and Design Guideline states that "raised roadway reflectors are an obstruction to bicycles. SRPM's should be used as an edge line demarcator only in hazardous areas of poor visibility where necessary to insure motor vehicle safety."

Idea: Continue the practice of installing RPM's on right edge lines at hazardous areas only.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT

OTHER COMMENTS:

5. Should left edge lines on divided highways be moved closer to the edge of the pavement or onto a paved shoulder to avoid narrowing a lane with SRPM's?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Idea: The design decision for Rt. 287 was to move edge lines 6" outward wherever possible, such as, where no curbs exist. Do not move edge lines outward if dirt accumulation may impair visibility of edge lines to the driver, such as near curbs.

AGREE DISAGREE DON'T KNOW

☐

1

☐

2

☐

3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

6. To what extent should double solid yellow center lines be separated to avoid painting over SRPM's?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Center lines have been modified by the Chief Engineer of Design to have a 6 inch gap between the lines, however, variation in lateral placement of the lines still results in painted reflectors.

Idea: Increase the spacing to 8 inches.

AGREE DISAGREE DONT'T KNOW

☐

1

☐

2

☐

3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

7. Should extensive use of the paint skip device on paint trucks be made rather than relying on operator skill to avoid painting over SRPM's?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Although this device has been installed on State painting trucks, problems have arisen with its use. Field inspections show no paint skips at SRPM installations and that the 6-inch spread between double center lines has not entirely eliminated the problem of painted reflectors.

Idea: Continue installation and maintenance of the paint skip device on line painting equipment and continue training for maintenance personnel regarding the need for and operation of the device.

AGREE DISAGREE DON'T KNOW

☐

1

☐

2

☐

3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

8. Should SRPM's be installed on all state roads?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

The Task Force on Long Life Pavement Markings recommended and the Division of Design accepted on February 18, 1986 that, pending adequate quality, Raised Pavement Markers be installed on all Freeways and Interstate Highways, and on State highways at locations determined by the Bureau of Traffic Engineering and Safety Programs based on an analysis of accident data.

Idea: Continue SRPM installations in accordance with this recommendation.

AGREE DISAGREE DON'T KNOW

☐

1

☐

2

☐

3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

9. Should SRPM's be installed on well-lighted roadways?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

The purpose of SRPM's is to provide delineation during wet-night conditions. During wet-night conditions, all lighting, including overhead lighting, tends to reflect off of a slick, wet road surface giving the appearance of distracting "streaks" on the road surface. Thus, SRPM's provide a useful function even when overhead lighting is present.

Idea: Install SRPM's in accordance with the Department Policy regardless of lighting being present.

AGREE DISAGREE DON'T KNOW

☐

1

☐

2

☐

3

REASON FOR DISAGREEMENT;

OTHER COMMENTS:

10. Please write any additional issues, problems, or ideas concerning "Placement and Warrants for Raised Pavement Markers."

C. SRPM INITIAL INSTALLATION ISSUES:

1. Is a faster casting adhesive available for different ambient temperatures?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Rapid set epoxy has been tried but its offensive odor was a source of complaints from several contractors who have used it. The research project "SRPM Wear and Improvement" will address this issue by evaluating faster setting adhesives that are odor free.

Idea: Start adhesive demonstrations to supplement the formal research.

AGREE DISAGREE DON'T KNOW

☐
1

☐
2

☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. What are acceptable limits of test failure of lenses prior to installation? How does this relate to lens performance after installation, specifically, validating lab acceptance in the field?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Acceptance limits for the strength, impact, and temperature cycling test have been initially set through specifications with additional information for resampling in case of initial failure. The research project "SRPM Wear and Improvement" may address this issue in some detail.

Idea: We should take the next step outlined in the 12/11/87 Design work plan which is to develop tests, not currently specified by Stimsonite, to address additional questions of concern to the Department with upgraded Laboratory testing equipment.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

3. When should Department quality assurance inspections of contractor SRPM installations be performed?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

The FHWA has insisted on a six-month acceptance delay.

Idea: Instead of the 6 month inspection, perform inspections as soon as possible after installation, which should show manufacturing and installation defects but not result in a rejection due to normal wear, as mentioned in Contract 2 "Testing Requirements and Other Related Aspects."

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

4. Please write any additional issues, problems, or ideas concerning "SRPM Initial Installation :"

D. SRPM MAINTENANCE ISSUES:

1. What is the effect of New Jersey's snowplow wheels on breakage, delamination, and cracking (otherwise referred to as premature damage) of the reflective insert?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

High rates of damage have been recorded at sites where plows are equipped with wheels. A large demonstration is being organized to test SRPM performance using the large Ohio-type snowplow shoes.

Idea: If SRPM performance is better with the Ohio-type shoes, install them on all snowplows and continue SRPM installation.

AGREE DISAGREE DON'T KNOW

☐

1

☐

2

☐

3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. What is the actual statewide average rate of damage and wear to the reflectors?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

There is a lack of unbiased data collected for reflector wear throughout the state. The rate of damage may vary according to site characteristics but this is not known. If there were an acceptable statewide average rate of wear, one should still expect wide variations in marker wear under different conditions as with any pavement marking system. The possibility of an extremely high rate of wear at certain locations exists and does not necessarily mean there is an overall problem with the system. A work plan is being drafted for a research project to determine the overall average and range of the rate of wear.

Idea: Continue new SRPM installations until more accurate data regarding the overall average rate of wear is determined through the research project.

AGREE DISAGREE DON'T KNOW

☐

1

☐

2

☐

3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

3. What is the tolerable statewide average rate of wear before money spent on SRPM's is considered "wasted?"

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐
4

*3 is the highest

In your opinion, a reflector installation on the average should last for:

(Check Only One)

- () an amount of time as determined by a cost-effectiveness study
- () the rate of wear doesn't matter as long as the reflector installation serves the public for as long as it lasts.
- () six months
- () one year
- () two years
- () three years
- () four years
- () five years
- () six years
- () more than six years,

OTHER COMMENTS:

4. How can reflector damage be minimized?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐
4

*3 is the highest

Idea: A casting that provides more protection for the reflectors should be investigated.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

5. How often should an SRPM installation be inspected while in use?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

There is a thought that the rate of wear will vary from road section to road section and that the rate of wear will remain mostly constant from year to year. This has been supported by conversations with the Ohio DOT.

Idea: Initial annual inspections should be done to determine the rate of wear for each road section followed by periodic checks.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

6. How can the rate of damage be predicted from known causes? (traffic, plowing, etc.)

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Some of the causes of reflector deterioration are suspect, however, there are likely to be other important wear factors that are not yet known. The research project "SRPM Wear and Improvement" will attempt to determine some of the causes of damage at specific sites.

Idea: Trying to predict route specific rates of damage from various combinations of causes should be abandoned. Continue trying to find the causes of damage.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

7. What is the best type of reflector adhesive to use for replacing reflectors in the castings?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

From a small scale study on Rt. 295 the use of construction adhesive alone showed promise. The butyl pad and primer system has been effective but slow and awkward to install. The butyl-primer plus adhesive method is currently in use and is suspected of causing early deterioration of the reflector. The use of epoxy does not seem to be better. Formal research and a large demonstration by Traffic Engineering and Safety Programs are in progress to find high performance adhesives.

Idea: Utilize the best adhesive system determined by the Bureau of Traffic Engineering and Safety Programs from their demonstration until formal research is completed.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

8. Please write any additional issues, problems, or ideas concerning "SRPM Maintenance."

Delineation Issue Resolution
Questionnaire No. 2

Roadside and Median Delineation

INSTRUCTIONS

1. Read each question and rate the importance of the issue. Use the following rating scale:

 0 = no importance
 1 = low importance
 2 = important
 3 = very important
 ? = not familiar with the question
2. Read any background and the idea given as a potential response to the issue, and check one box indicating whether, in your professional opinion, you agree with the idea, you disagree with the idea, or that you don't know.
3. If you disagree with an idea mentioned as a possible answer to an issue, please give a reason.
4. Include any comments you may have.
5. At the end of each section add any issues you may have in mind.

DELINEATION ISSUES RESOLUTION QUESTIONNAIRE

E. Guiderail Delineation Issues:

1. Which guiderails should be delineated?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

☐

*3 is the highest

4

Idea: Delineate all guiderail statewide regardless of distance from the pavement unless engineering review shows otherwise.

AGREE DISAGREE DON'T KNOW

☐
1☐
2☐
3

REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. Will guiderail delineators be maintained if they are installed?

IMPORTANCE OF QUESTION
SCALE 0 - 3* or ?

☐

*3 is the highest

4

Idea: According to recent research findings little maintenance should be required. Add the delineators to the list of items to be maintained and they will eventually be maintained in a priority order as are all other items.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

3. What is a suitable spacing interval for guiderail delineaters?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

4

According to a recent research study done by the Department, guiderail delineator spacing was recommended to be 80 ft. on tangent roadway sections and 40 ft. on curves.

Idea: Several recent installations have been made with this spacing, which should be continued.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

4. Should guiderail delineation be markedly different in appearance from post mounted delineators?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

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Idea: No, because the 80- and 40-foot spacing already produce a different appearance from post delineators.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

5. Please write any additional issues, problems, or ideas concerning "Guiderail Delineation:"

F. Center Barrier Delineation Issues:

1. Past research has identified an acrylic cube corner reflector mounted on a flexible polymeric base and glued to the top of the barrier as the best mechanical method for delineating concrete barriers under normal conditions.

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

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Idea: Drop consideration of all other devices and methods for delineation of permanent barriers and implement the research results whenever concrete barriers are reflectorized unless special conditions exist.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. Should reflective sheeting be used for center barrier delineation in certain areas to reduce vandalism and how should these areas be identified?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

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There is no widespread experience on this subject. However, vandalism has been documented on the U.S. 1 Freeway near Trenton at the Whitehead Road interchange.

Idea: Use the vandal resistant delineators on highways where vandalism is probable.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

3. How can maintenance of center barrier delineators be done to address unexpected removal of groups of reflectors due to accidents?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

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Idea: The normal maintenance observations should suffice.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

4. Where and under what conditions should center barrier delineators be installed?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

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Idea: Install center barrier delineators statewide on the top of all permanent concrete center barriers that are 32 inches high or less.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

5. Will recommendations for delineating plain barriers work for barriers with glare screens?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

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Idea: Delineators should be mounted on top of the concrete barriers at the bottom of the glare screen.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

6. What type of center barrier delineators are suitable for dirty urban areas or is delineator cleaning needed?

IMPORTANCE OF QUESTION
SCALE 0 - 3* or ?

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*3 is the highest

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Some areas of the state may be so dirty that hand cleaning would be the only solution, although impractical.

Idea: Do not install delineators in areas where they can't be kept clean.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

7. What spacings should be used for center barrier delineators?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

Recently completed research has found spacings of 80 feet and 40 feet (depending on road geometry) to provide good barrier delineation.

Idea: Use the research results for delineator spacing on state roads.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

8. Will recommendations for delineating 32-inch high concrete barriers work for higher barriers?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

Delineators may be mounted on top of barriers as high as 48" because this height is the same height as post delineators and guiderail delineators but there may be light blockage from the barrier itself.

Idea: Delineate concrete barriers higher than 32-inches in the same way as 32-inch barriers are delineated.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

9. Should all concrete barriers be delineated, including those used on the right of traffic and for dividing local and express traffic moving in the same direction?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

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Idea: Delineate all concrete barriers regardless of location and use white reflectors for barriers dividing traffic moving in one direction.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

10. Please write any additional issues, problems, or ideas concerning "Barrier Delineation":

G. Post Mounted Delineator (PMD) Issues:

1. Where should flexible posts be used versus rigid posts?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

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The flexible posts are usually cost-effective because although they are more expensive than steel posts, they are capable of surviving impacts that would ruin steel posts.

Idea: From the California DOT, flexible delineator posts should be used under the following conditions:

1. On existing roadways to replace damaged posts at locations which involve a combination of short radius curves (less than 150 feet) and high approach speed. (In accordance with the New Jersey DOT Materials Committee recommendation).
2. At high damage areas where the average expected life of a metal delineator post is less than one year.
3. Areas where metal posts have less than a 25 percent survival rate.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. What colors should the post be for optimum visibility under all conditions?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

4

Since PMD's are one of the few delineators that works at all when roads are snow covered, they should be self-contrasting to maximize contrast with different backgrounds, especially snow. Zwahlen recommends that PMD's have black and white stripes which are self contrasting and a 1" x 18" vertical reflective strip.

Idea: A demonstration of this device should be arranged.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

3. From a driver's perspective, is there a possibility of mistaking PMD's for raised pavement markers at night creating the illusion of an extra lane?

IMPORTANCE OF QUESTION
SCALE 0 - 3* or ?

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*3 is the highest

4

This doesn't seem to be a problem, however, the use of the 1" x 18" vertical reflective strip recommended by Zwahlen, should eliminate any confusion.

Idea: Arrange a field demonstration of the product.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

4. Roadside mowing operations have difficulty avoiding the posts, how can this be alleviated?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

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Idea: Supervise the operators to avoid cutting the posts and replace damaged posts.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

5. Are post mounted delineators maintained adequately after they are installed?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

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Idea: Continue the current maintenance procedure.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

6. Please write any additional issues, problems, or ideas concerning "Post Mounted Delineators:"

H. Chevron Sign Use Issues:

1. Where should chevrons be used rather than regular Post Mounted Delineators?

IMPORTANCE OF QUESTION
SCALE 0 - 3 OR ?

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*3 is the highest.

4

Research by the Virginia DOH found Chevrons provided superior delineation on sharp curves of radius 1000-ft. or less.

Idea: The NJDOT should utilize chevrons in these instances at the spacing given by the MUTCD.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. Please write any additional issues, problems, or ideas concerning "Chevron Signs:"

Delineation Issue Resolution
Questionnaire No. 3

Construction Zone Delineation

INSTRUCTIONS

1. Read each question and rate the importance of the issue. Use the following rating scale:
 - 0 = no importance
 - 1 = low importance
 - 2 = important
 - 3 = very important
 - ? = not familiar with the question
2. Read any background and the idea given as a potential response to the issue, and check one box indicating whether, in your professional opinion, you agree with the idea, you disagree with the idea, or that you don't know.
3. If you disagree with an idea mentioned as a possible answer to an issue, please give a reason.
4. Include any comments you may have.
5. At the end of each section add any issues you may have in mind.

DELINEATION ISSUES RESOLUTION QUESTIONNAIRE

I. CONSTRUCTION ZONE PAVEMENT MARKING ISSUES:

1. Should interim abbreviated pavement markings (i.e. 2 ft. stripe every 40 ft. etc.) be used on newly paved areas in order to allow earlier use by traffic before permanent striping can be applied?

IMPORTANCE OF QUESTION
SCALE 0 - 3* or ?

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*3 is the highest

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Idea: Maintain the current practice of opening a road to traffic only after permanent striping has been applied.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. Are there any problems with removal of temporary pavement marking tape?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

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Temporary pavement marking tape is difficult to remove from bridge decks that have a transverse saw cut pattern.

Idea: Use only TRPM's on saw-cut decks for good temporary delineation and easy removal.

AGREE DISAGREE DON'T KNOW

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REASONS FOR DISAGREEMENT:

OTHER COMMENTS:

3. Please write any additional issues, problems, or ideas concerning "Construction Zone Pavement Markings:"

J. TEMPORARY RAISED PAVEMENT MARKER (TRPM) ISSUES:

1. What should be the spacing of day/night visible TRPM's when they are used alone without pavement marking tape?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

4

The FHWA guidelines of 1985 recommend a TRPM spacing of 5 to 10 feet when TRPM's are used to simulate a solid line. The 5 ft. spacing is recommended for tapers, lane shifts, and curves; the 10 ft. spacing is suitable for tangent roadway geometry.

Idea: Adopt this spacing for Department use.

AGREE

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. Should day/night visible TRPM's be used as a replacement for temporary pavement marking tape?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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Idea: Introduce the use of day/night visible TRPM's by themselves (without tape) for simulating lane lines in construction zones.

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

3. Should the adhesives sold with TRPM's be used?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* or ?

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*3 is the highest

4

A recent Department research project evaluated numerous adhesives and found that the manufacturers' recommendations for adhesives should not always be followed.

Idea: Guidelines established by recent research should be confirmed by larger scale demonstrations of specific adhesives found to have good potential with specific temporary markers.

AGREE

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

4. Please write any additional issues, problems, or ideas concerning "TRPM's:"

K. CHANNELIZER ISSUES

1. Type III barricades are being used as channelizers in taper areas even though this use is not specified in the MUTCD or any other publication. Should vertical tall panels (mounted on barrels) be used in place of some or all of the barricades in taper areas?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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4

*3 is the highest

Department research found that the vertical panels work better than barricades.

Ideas: The vertical tall panels mounted on barrels should be used where determined by the Bureau of Traffic Engineering and Safety Programs.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. Are barrels stable enough in long-term construction zones?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

When designed and ballasted with sandbags, as is specified, barrels are quite stable and suitable for use in long term construction zones.

Ideas: Continue the current design and use of barrels as channelizers.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

3. Do barrels require cleaning to maintain night reflectivity?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

Ideas: They should be cleaned as needed to maintain reflectivity.

AGREE	DISAGREE	DON'T KNOW
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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

4. What spacing is required for channelizers used to delineate temporary exit and entrance ramps?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

The Department Traffic Control Plan requires a channelizer spacing of 20 ft. on the left side and 30 ft. on the right side of temporary ramps.

Idea: Use this spacing until current research into optimum spacing of channelizers is completed.

AGREE	DISAGREE	DON'T KNOW
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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

5. Do cones require ballasting to maintain stability, especially in high-speed heavy traffic areas?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

4

There is a problem with motorist disrespect for road closures made with cones and knocked-down cones increases this problem. Using two cones together or procuring specially ballasted cones should be investigated.

Idea: Evaluate different cones on the market to find products with greater stability.

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

6. Are current methods of cone reflectorization adequate?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

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Idea: Continue the current method of using reflectorized cone collars for night visibility.

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

7. What is the suitability of cones for night lane closures?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

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The visibility distance of cones is much less at night than other channelizers.

Idea: Avoid the use of cones as channelizers for night lane closures. They may be used at night to direct traffic at points of permanent closure, for example at toll plazas.

AGREE

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

8. Please write any additional issues, problems, or ideas concerning "Channelizers":

L. CONSTRUCTION BARRIER DELINEATION ISSUES:

1. What is the best way to delineate construction zone concrete barriers?

IMPORTANCE OF QUESTION
SCALE 0 - 3* OR ?

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*3 is the highest

4

Current practice is to use 6" x 12" reflective sheeting panels mounted on construction zone barriers at 100 ft. intervals for tangents and 50 ft. intervals on curves. This method of delineation has been highly successful.

Idea: Continue using reflective sheeting panels for barrier delineation.

AGREE DISAGREE DON'T KNOW

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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. Please write any additional issues, problems, or ideas concerning "Construction Barrier Delineation:"

M. BARRICADE ISSUES:

1. What kind of maintenance is needed for barricades?

IMPORTANCE OF QUESTION:
SCALE 0 - 3* OR ?

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*3 is the highest

4

Although the barricades were originally designed to be repairable, contractors find it more convenient to simply replace damaged barricades.

Idea: Repair or replacement by contractors are equally acceptable as long as the devices are maintained in good condition.

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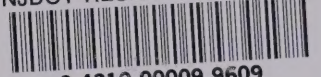
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REASON FOR DISAGREEMENT:

OTHER COMMENTS:

2. Please write any additional issues, problems, or ideas concerning "Barricades:"

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